# NATIONAL SUMMARY: NATIONAL ASSESSMENTS



There are three sets of national assessments within this section. First, gaps in the mapping and monitoring data are identified and their impact on developing an assessment of the national condition of coral reef ecosystems is discussed. Second, there is a national assessment on the current status of coral reef ecosystems by jurisdiction. Since much of the data has yet to be gathered, these are mostly qualitative, brief summaries (three pages or less) and were derived from the jurisdictional reports. Third, a national assessment of temporal and spatial trends in coral reef ecoystems concludes the section.

Mapping and monitoring the coral reefs to 1) fill in data gaps and 2) create a comparable set of data for all jurisdictions is the core of the program and vital to assessments of status and trends. The USCRTF initiatives to provide this information began in 2000 but have a long way to go. Mapping should be completed in 2009; monitoring is a long-term commitment. Until that information is available, rough estimates compiled from a variety of sources can be used to compare data among jurisdictions.

*Figure 66. Aerial photographs have been acquired and interpreted to produce benthic habitat maps (Photo: National Ocean Service).*

**Gaps in Habitat Mapping** – Until recently, not a single State, Commonwealth, or Territory had its coral reef resources characterized and mapped with aerial photography and ground verification. The extent of the coral reefs and characterization of associated benthic habitats off the U.S. and Freely Associated States is essentially unknown. This lack of statistically comparable spatial data prevents direct comparison of other data as well.

- Credible, comparable maps of reef and associated benthic habitats were completed for Puerto Rico and the USVI by NOAA and its partners in 2001. Those were used for this report.
- About half of Florida's entire coral reef ecosystem has been mapped using methods similar to those for Puerto Rico and the USVI (Fig. 66). Mapping efforts covered the original boundaries of the Florida Keys National Marine Sanctuary in the 1990s (FMRI/NOAA 1998). Recently, a portion of the Dry Tortugas region was characterized (Schmidt *et al.* 1999). The rest of Florida's coral reef ecosystem has yet to be mapped. For this reason, the Florida values reported in this section and in the regional report that follows, where indicated, are for the FKNMS and not statewide.
- Elsewhere, benthic habitat mapping is underway. Estimates of coral reef area for these regions were taken from the literature.

Literature estimates vary widely. For example, published estimates for total coral reef habitat of the NWHI range from 3,475-4,247 mi$^2$ (9,000-11,000 km$^2$) (e.g., Hunter 1995). Most available estimates were calculated from **bathymetry**[77]. The maps from which those estimates were derived had varying levels of detail and accuracy.

Differences among regions may also be biased in the methodology and a general lack of information. Some of the literature estimates were based on the 100 m bathymetric line (i.e., the entire area equal to or less than 300 feet, regardless of habitat type), significantly over-estimating the shallow reefs[78] within a region. Where this is the only data available, it was used for this first report.

[77] Lines connecting equal depths on printed maps.
[78] Those in water less than 150 ft.

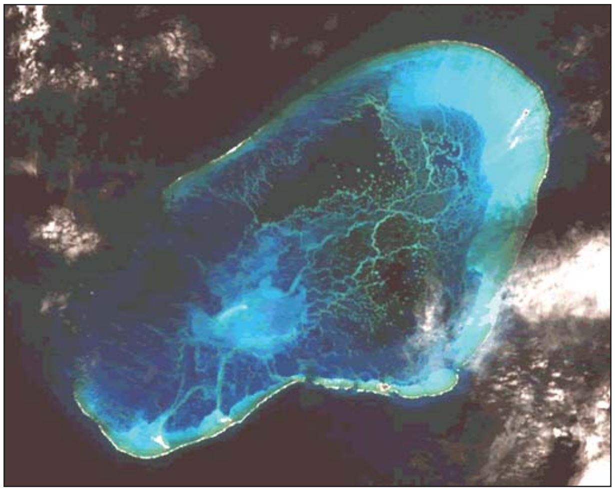


*Figure 67. Landsat 7 satellite imagery is being used to map the remote Northwestern Hawaiian Islands (Imagery processed by NOS Coral Reef Mapping Team).*

Reliable data on benthic communities is being developed, primarily from the USCRTF/NOAA benthic mapping effort. In 2000, NOAA initiated a program to map U.S. coral reef ecosystems and related benthic habitats by 2009 (USCRTF 2000). As mentioned before, by the end of 2001, NOAA had completed mapping benthic underwater habitats off Puerto Rico and the USVI. They have been mapping habitats off the Main Hawaiian Islands since 2000. By the end of 2002, there should be benthic habitat maps for about one third of the Hawaiian shoreline. The remaining two-thirds and possibly an update of the 2002 maps will be completed in 2005 (Fig. 67). In 2002, mapping activities are scheduled to begin in American Samoa, Guam, and the CNMI using IKONOS satellite imagery for initial map development.

**Gaps in Ecosystem Monitoring** – To be able to follow the status and trends of the changing condition of coral reef ecosystems, comparable long-term monitoring is needed. Not all jurisdictions have the same capacity to conduct monitoring programs. This varies for both the geographic area and the parameters monitored. As a result, data from some areas is more definitive than from others.

The most extensive spatial and long-term temporal monitoring is conducted over much of the Florida Keys National Marine Sanctuary. Sanctuary-wide monitoring of water quality, seagrasses, and coral and hard-bottom communities began in 1994 under a Water Quality Protection Program jointly undertaken by NOAA and the U.S. Environmental Protection Agency (USEPA). In 1997, the FKNMS implemented a network of fully protected zones[79] and a zone monitoring program. The program was initiated to determine whether the zones met the objectives of reducing pressure on heavily used reefs, preserving biodiversity, facilitating research, and reducing conflicts among resource users. It monitors many parameters at around 100 sites.

Hawai‘i has the next best monitoring coverage and program longevity. Since 1999, a collaboration of the University of Hawai‘i, the Hawai‘i Department of Land and Natural Resources, federal agencies, and NGOs, the Coral Reef Monitoring and Assessment Program (CRAMP) has been monitoring at least 30 coral reef sites off the Main Hawaiian Islands.

Although there has been long-term monitoring at a number of reef sites on other U.S. islands (e.g., sites off the USVI and American Samoa), both spatial coverage and parameters are far less comprehensive.

With considerable support from Congress, the USCRTF agencies[80] are taking the necessary steps to build capacity for long-term monitoring using consistent, comparable sampling methods and protocols. Since 2000, substantial grants support a variety of projects undertaken by island agencies[81] to map, conduct ecological assessments, characterize benthic habitats, and inventory the species that depend on them, monitor ecosystem health, and conserve reef resources (Fig. 68). Funding for managers of marine protected areas with coral reefs[82] was enhanced during FY01 and FY02 to initiate or continue monitoring efforts. In 2002, similar assistance is planned for the Freely Associated States. The nation's managers have committed to building long-term monitoring capacity.

*Figure 68. New monitoring is being supported by USCRTF grants (Photo: James Maragos).*

[79] Also called no-take marine reserves.
[80] Particularly the DoI and the DoC.

## Status of Coral Reef Ecosystems

For this first report, assessments are presented as 11 short summaries on the condition of coral reefs in the United States and the Pacific Freely Associated States. For the most part, these reports are based on information contained within the jurisdictional reports that follow this National Summary.

**Condition of Florida's Coral Reef Ecosystems** – Florida's coral reefs are extensive and interspersed with sand, seagrass, and hardbottom communities, from off southeastern shores (Vero Beach to Miami Beach), westward through the Florida Keys to the Dry Tortugas. Coral reef habitat is almost continuous along the Florida Reef Tract, parallelling the Keys for 220 mi from Fowey Rocks near Miami and terminating west of the Dry Tortugas. Discontinuous and less biologically diverse coral reef communities continue northward along western Florida shores to the Florida Middle Grounds, a series of submerged pinnacles rising to within 60-80 ft of the surface, about 100 mi northwest of St. Petersburg (Fig. 69).

Florida's total coral reef and colonized hardbottom area covers 1,172 $mi^2$ (3,035 $km^2$), of which 495 $mi^2$ (1,281 $km^2$) lies within the Upper, Middle, and Lower Keys (FMRI/NOAA 1998); 129 $mi^2$ (335 $km^2$) in the Dry Tortugas (Ault *et al.* 2001); 63 $mi^2$ (164 $km^2$) along the southeastern coast of Florida; 24 $mi^2$ (62 $km^2$) in the eastern Gulf of Mexico (excluding the Florida Middle Grounds); and 461 $mi^2$ (1,193 $km^2$) is attributed to the Florida Middle Grounds (Florida Fish and Wildlife Conservation Commission 2001). Coral reefs and adjacent habitats include nearshore patch reefs, mid-channel reefs, offshore patch reefs, bank or transitional reefs, deep reefs, sand/soft bottom areas, seagrass beds, and fringing mangroves.

Florida Keys – The Florida Keys are home to the third largest shallow-water coral reef in the world and the only emergent reef ecosystem found off the continental United States. This unique marine habitat is under protection, with the extreme northern end managed by the Biscayne National Park and the remainder of the reef tract managed by NOAA and the State of Florida as the Florida Keys National Marine Sanctuary (FKNMS or Sanctuary), and the Dry Tortugas National Park.

The Florida Keys has historically supported diverse and healthy marine communities despite being located at the northernmost range of many Caribbean coral species. At this time, the coral reefs of the region are in decline, as evidenced by decreases in coral coverage, species fluctuations, and disease (Jaap *et al.* 2001). One program documented a 36.6% decline in coral cover at monitoring stations during the period between1996 and 2000 (Jaap *et al.* 2001). Significant gains and losses of several stony coral species have occurred as well, but to date no loss of species has occurred Sanctuary-wide.

While it is difficult to ascertain the exact causes of coral mortality and community change in the Sanctuary, declines may generally be attributed to natural and anthropogenic impacts. Over the past two decades the reef tract has been hit by a succession

*Figure 69. Map of South Florida and its MPAs (Photos: Biscayne and Everglades National Parks and FKNMS). For all maps, yellow stars denote MPAs, red stars are no-take Reserves, and blue lines delineate the larger MPAs.*


[81] Puerto Rico, USVI, Hawai'i, American Samoa, Guam, and the CNMI.

[82] For example, the Florida Keys National Marine Sanctuary and the Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve.

Figure 70. Prop scar damage to seagrass (Photo: Harold Hudson).

of natural disasters, including hurricanes, diseases, and coral bleaching. Hurricanes have had visible effects on populations of attached bottom animals and algae in most areas (Aronson *et al.* 2001). The number of new diseases and the extent of infection have been increasing since 1996 in shallow areas; in particular, there is increased coral mortality from a complex of diseases (e.g., white-plague, white-band, and white-pox) (Dustan 1999, Jaap *et al.* 2001).

Coral bleaching in the past 20 years has resulted in significant mortality. For example, the blade fire coral suffered 80-90% mortality following a 1997-1998 bleaching episode off the Florida Keys (W. Jaap pers. comm.); the population has remained low throughout most of the area. Mortality from bleaching often occurs with massive kills of other invertebrates and fishes. Extreme mortality events, such as the 1983 Caribbean-wide die-off of the long-spined sea urchin, have indirectly affected corals by the loss of an important algal grazing species.

Figure 71. Staghorn coral spawning off the southeastern coast of Florida (Photo: National Coral Reef Institute).

Direct destruction of corals, seagrasses, and hardbottom communities caused by inadvertent human actions, has increased dramatically over the last several decades. Boat groundings, propeller scarring (Fig. 70), careless anchoring, and direct contact by snorkelers and divers have damaged hundreds of miles of sensitive marine habitats in the Florida Keys, further stressing an ecosystem already struggling to withstand natural impacts. Most of these pressures stem from the three million annual visitors (Leeworthy and Vanasse 1999) and 80,000 year-round residents of the Florida Keys. The residents and tourists in adjacent Miami-Dade county (2.49-2.56 million) place additional pressures on the fragile reefs of the Florida Keys.

In addition to habitat loss, declining water quality affects the Florida Keys marine environment. Inadequate wastewater and stormwater management degrade nearshore areas. Eutrophication is a documented problem. Though several improvements have been undertaken, such as an upgrade from an ocean outfall to deep well injection of treated wastewater for the City of Key West, additional advancements are needed Keys-wide to comprehensively address this problem. Reduced freshwater flows to Florida Bay from upstream water management have increased plankton blooms, sponge and seagrass die-offs, and fish kills, impacting critical nursery and juvenile habitat for a variety of reef species.

Serial overfishing has dramatically altered fish and other animal populations on the reef, contributing to an imbalance in the relationships that are critical to sustaining a diversity of organisms (Ault *et al.* 1998). Five species of fish in the Florida Keys and another six species in Florida Bay are at risk of extinction (Musick *et al.* 2000). Those authors contend these species are threatened because the Florida Keys has undergone extensive development over the last 30 years, with much of the original habitat degraded or destroyed, while Florida Bay has experienced increased turbidity and altered freshwater influx.

The Florida Keys National Marine Sanctuary was designated in 1990 in an attempt to offset impacts from these and other environmental pressures and reverse trends in reef degradation. Through the development and implementation of a comprehensive management plan, key problems such as degradation of habitats and water quality are addressed Sanctuary-wide through regulatory and non-regulatory strategies. A network of marine zones that includes 24 fully protected marine reserves has been implemented to provide additional protection to sensitive species and habitats. The fully protected zones encompass approximately 65% of shallow coral reefs in the Sanctuary. Initial monitoring of these areas suggests improvements in some key reef species (snappers, groupers, and spiny lobsters; Bohnsack *et al*. 2001).

Southeastern Coast – Characterized by three lines of discontinuous reefs that run parallel to the shoreline, this reef system is covered by algae and small soft corals, with an Anastasia limestone substrate and worm reef (*Phragmatopoma*). The stony coral cover and diversity is lower here than in the Florida Keys.

The outermost reef has a complex three-dimensional structure with a high diversity of stony (scleractinean) corals and an abundance of octocorals and large barrel sponges (*Xestospongia muta)*. For the past three years, sexual spawning has been observed on outcrops of staghorn coral (Vargas-Ángel and Thomas in press, Fig 71).

Based on the condition of coral and fish populations, reef communities on the southeastern coast of Florida are in relatively good condition, but there are issues. The Florida Current (the Gulf Stream) occasionally brings algal blooms onto the reefs. Since 1989, algal blooms of an invasive green alga called dead-man's fingers (*Codium isthmocladium*) to the north and a cyanobacterium *(Mictocoleus lynbyaceus*) to the south are commonly found. Blooms of dead man's fingers have reached massive proportions on some reefs off Palm Beach County.

Besides overfishing, fish kills and disease have been recurring problems for reef populations on the southeastern coast. Fish kills are common during cold-water upwelling events. In June 1980, hundreds of thousands of reef fish died within a very short time throughout the region, apparently from *Brooklynella*, a disease that continues to plague reef fish. There were severe outbreaks again in 1997, 1998, and 2000.

Within the past decade, a growing number of alien species have been identified from embayments and

*Figure 72. Turbid water from dredging (Photo: National Ocean Service Photo Gallery).*

reefs in South Florida and the Gulf of Mexico. Most of these species are foreign to North American waters and were introduced by either ship hull fouling or ballast water dumping (USGS 2002). The majority of Florida's marine fish introductions comes from released aquarium fish, with occasional reports of various exotic species among native reef fish.

Throughout Southeast Florida, dredging for beach renourishment, channel deepening, and waterway maintenance have degraded water quality within reef habitats (Fig. 72). Most dredging occurs from Dade to Martin Counties (Miami to Vero Beach). In addition, ocean outfalls dump millions of gallons of treated sewage into coastal waters each day. Water control priorities in the larger South Florida region often put near-shore reefs at risk when millions of gallons of fresh water are dumped into the ocean through coastal canals.

Biscayne National Park, one of the largest parks in South Florida with beautiful coral reef and mangrove ecosystems, is also in danger. In or adjacent to Biscayne Bay, including Miami-Dade County and a sprawling suburbia, are threats from toxic contaminants, runoff from a huge municipal dump, a nuclear power plant, and heavy small vessel traffic with resulting groundings.

Florida Middle Grounds – These bank formations consist of two north-to-northwesterly parallel ridges separated by a valley. Most tropical species cannot live in these habitats because of the region's cooler water temperatures. Biologically, they are equally temperate and tropical, differing from the reefs of the Florida Keys and Flower Garden Banks in the western Gulf. Coral cover may be as high as 30% on some reef pinnacles.

Recent SCUBA and submersible expeditions to the Florida Middle Grounds examined a number of reef structures and found them apparently healthy (W. Jaap pers. obs.). The isolation and distance of this area from populated shorelines likely provide protection from pollutants and heavy recreational fishing activity.

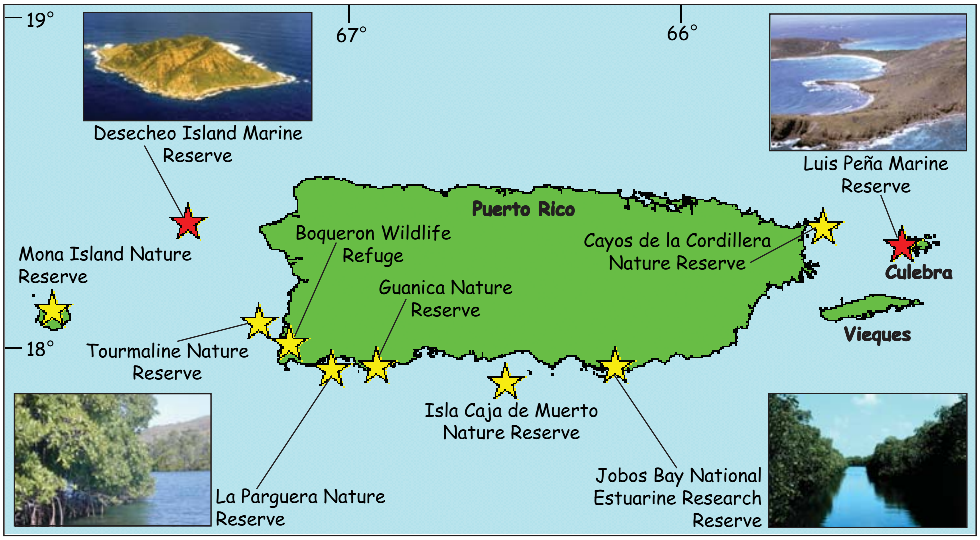
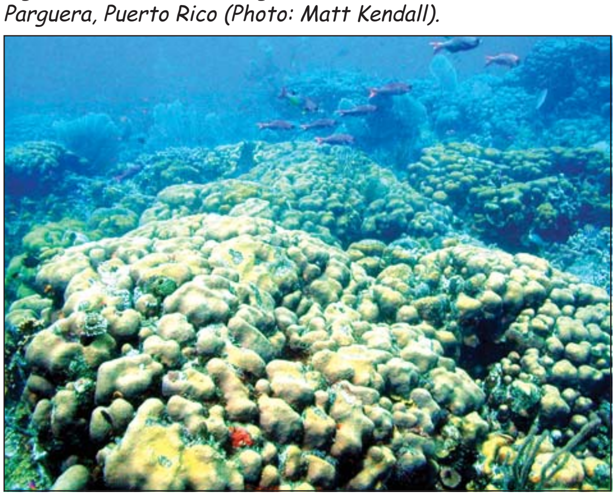



*Figure 73. Map of Puerto Rico and its MPAs (Photos: John Christensen, USFWS, and NOAA).*

**Condition of Puerto Rico's Coral Reef Ecosystems** – The islands of the Commonwealth of Puerto Rico, with a combined total land area of about 3,435 $mi^2$ (8,897 $km^2$, roughly the size of Rhode Island) and a linear coastline of 385 mi, are the easternmost islands of the Greater Antilles, located between La Hispaniola and the Virgin Islands (Fig. 73). The islands lie on a submarine platform and include Puerto Rico, Vieques, Culebra, Culebrita, Desecheo, Mona, and Monito.

With the exception of Monito Island, NOAA recently mapped Puerto Rico's coral reef ecosystem and associated benthic habitats to about 65 ft. The mapping delineated a total coral reef ecosystem area of 1,934 $mi^2$ (5,009.6 $km^2$). Coral reef and colonized hardbottom habitat comprised 292 $mi^2$ (756.2 $km^2$, 15.1% of the total reef ecosystem), total seagrass habitat covered 241 $mi^2$ (624.8 $km^2$, 12.5% of the ecosystem), macroalgal-dominated areas covered 37 $mi^2$ (96.7 $km^2$, 1.9%), and the mangroves fringing the islands covered 28 $mi^2$ (72.6 $km^2$, 1.4%).

*Figure 74. Reef with a large amount of coral cover off La Parguera, Puerto Rico (Photo: Matt Kendall).*



Coral reefs off Puerto Rico near La Parguera, Desecheo Island, and Vieques Island have the highest abundance and percent cover of living coral (Fig. 74), although these reefs have been degraded by a host of human and natural impacts. Results from recent studies of Desecheo Island indicate its coral reefs are probably the best-developed and healthiest in Puerto Rico, with about 70% coral cover and high water clarity (Armstrong *et al.* 2001).

Throughout the area, staghorn and elkhorn coral populations have declined over the last 25 years from hurricane damage, white-band disease, and corallivorous mollusks (Goenaga 1991, Bruckner *et al.* 1997, Williams *et al.* 2000). Extensive thickets of elkhorn coral formerly dominated many shallow coral reef habitats (0-16 ft).

White-band disease has had a devastating impact on what had been vast stretches of apparently healthy elkhorn coral off the eastern coast of Puerto Rico (Goenaga and Boulon 1992). A few outer reefs still had extensive elkhorn thickets as recently as 1998, but Hurricane Georges heavily damaged those (Morelock *et al.* 2001). Staghorn coral, also damaged by Hurricane Georges, has recovered considerably from white-band disease. Although the disease is prevalent, flourishing stands can be found in shallow back-reef sites off San Cristóbal. But on reefs off La Parguera where large numbers of staghorn coral were lost during the 1980s and early 1990s (Williams *et al.* 2000), populations have continued to decline over the last decade (Bruckner *et al.* 1997, Morelock *et al.* 2001). The disease is also prevalent among elkhorn coral colonies.

Black-band disease was first observed in Puerto Rico in 1972 but occurs less here than elsewhere. White plague type II disease affects more than 50% of the brain coral population on one inner reef near La Parguera (Bruckner and Bruckner 1997). Yellow-blotch disease was first recorded in 1996, and by 1999 had affected 50% of the massive boulder star corals off the western coast of Mona. Now it affects all reefs in that area (Bruckner and Bruckner 2000). Most other diseases reported in the literature have been observed as well (A. Bruckner unpub. obs).

Overgrowth by sponges and other invertebrates has been a minor source of coral mortality on reefs that was first noted by Vicente (1978). The encrusting sponge (*Cliona* spp.) has covered substrates previously covered by elkhorn coral and is now overgrowing many other species of corals in a number of locations.

Hurricanes and tropical storms have damaged the reefs over the past 20 years. Hurricane Georges in September 1998 devastated the elkhorn corals and other shallow reef environments near La Parguera (Morelock *et al.* 2001). While Hortense in 1996, Marilyn in 1995, and Hugo in 1989 had weaker winds, they had heavier rains, impacting the shallow reefs with freshwater.

To date, fishery resources off Puerto Rico have shown the classic signs of overfishing. Reef fisheries are now only 31% of what they were in 1979 (C. Lilyestrom unpub. obs.).

The decline in abundance of large fish and the massive mortality of the long-spined urchin represent a major shift in community structure of the Puerto Rican reefs. Likewise, heavy fishing of the spiny lobster has substantially reduced its numbers

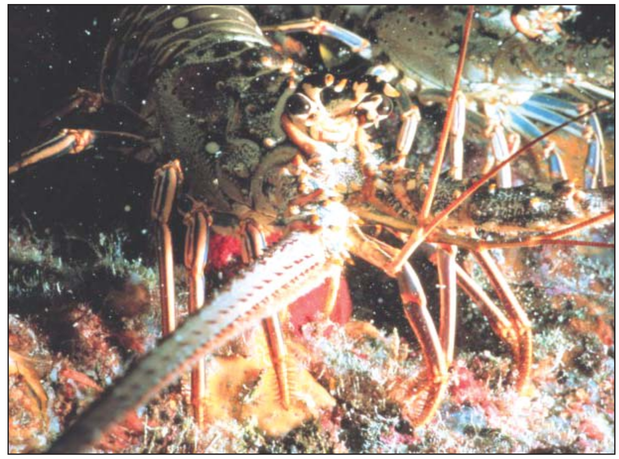


*Figure 75. The spiny lobster has experienced heavy fishing pressure in Puerto Rico (Photo: NOAA OAR/NURP).*

(Fig. 75), affecting populations of corallivorous mollusks, one of its prey.

Activities related to urbanization have degraded coastal water quality in Puerto Rico. Sedimentation and high turbidity have been associated with development have degraded a variety of reef systems around the island. In their qualitative inventory of reefs, Goenaga and Cintrón (1979) noted a high amount of sedimentation affected reefs of the northern coast and in bays used for ocean cargo on the southern and western coasts (e.g., Guayanilla, Mayagüez).

A periodic problem for near-shore water quality is illegally discharged wastes. Since 1991 on a yearly basis, the USEPA has provided compliance assistance to hundreds of regulated businesses and facilities (USEPA 2002). This is still a problem in particular areas. A major rum processing plant regularly exceeds permit limits for oxygen demand and solids in its stormwater runoff flowing into San Juan Bay (ten months between 1997 and 2000). Additionally, this company has been cited by the USEPA for discharging rum effluent directly into the Bayamon River Channel.

**Condition of USVI's Coral Reef Ecosystems** – The U.S. Virgin Islands (USVI) lie approximately 1,000 nmi southeast of Miami and 45 nmi east of Puerto Rico, and include the primary islands of St. Croix, St. John, and St. Thomas, as well as offshore cays. Around the islands are fringing, deep wall and shelf-edge, and patch reefs, some with spur-and-groove formations. Only St. Croix has barrier reefs. Bank reefs and scattered patch reefs

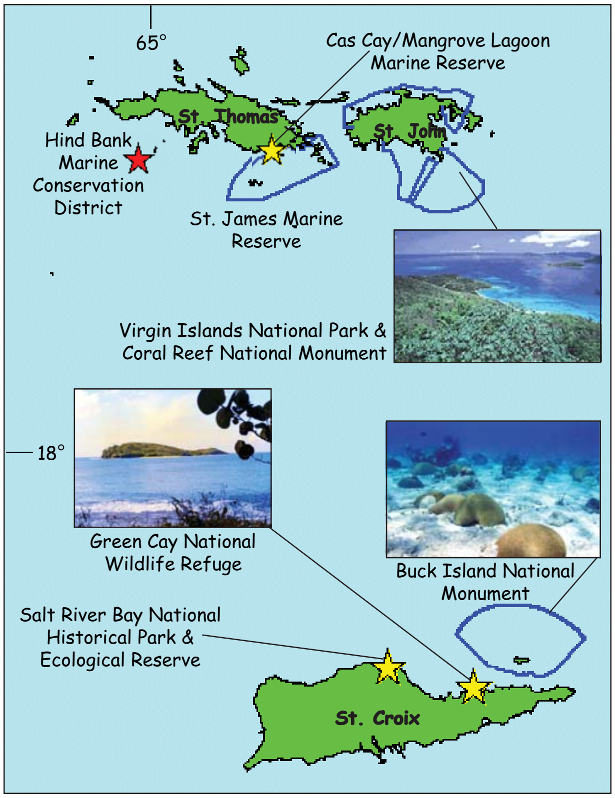



*Figure 76. Map of the U.S. Virgin Islands and its MPAs (Photos: Matt Kendall, NPS, and USFWS).*

with high coral diversity occur on geological features offshore at greater depths (Fig. 76).

Recently NOAA mapped USVI coral reef ecosystems and associated habitats to about 70 ft and delineated a total coral reef ecosystem area of 350 mi$^2$ (906.3 km$^2$, Kendall 2001, Monaco *et al.* 2001). Deeper water reef habitats off the USVI islands have yet to be mapped.

A diverse array of stresses have degraded USVI coral reefs, associated marine ecosystems, and the fishery resources dependent on them. Natural disasters have also degraded USVI reefs. Eight hurricanes over the past 20 years have had dramatic impacts and given the reefs little chance to recover. Hurricanes David and Hugo were especially damaging, killing coral and impacting reef tracts.

Macroscopic algae are periodically abundant, increasing after storms and disease had killed corals. Although long-term data exists only for St. John, large, dense seagrass beds have dramatically declined, all but disappearing in popular anchorages.

Coral mortality from disease has been substantial over the past two decades. White-band disease, black-band disease, plague type II, a sea fan disease, and possibly other undetected diseases all have impacted coral reef health.

Most dramatic has been the demise of the elkhorn coral. Impressive stands reported in the 1970s and 1980s are now graveyards from storms and white-band disease (Fig. 77). Branches and fragments are dead, interspersed with algal-covered skeletons still in position. In places, living elkhorn coral cover has fallen from 85% in 1976 to a low of 5% in 1988.

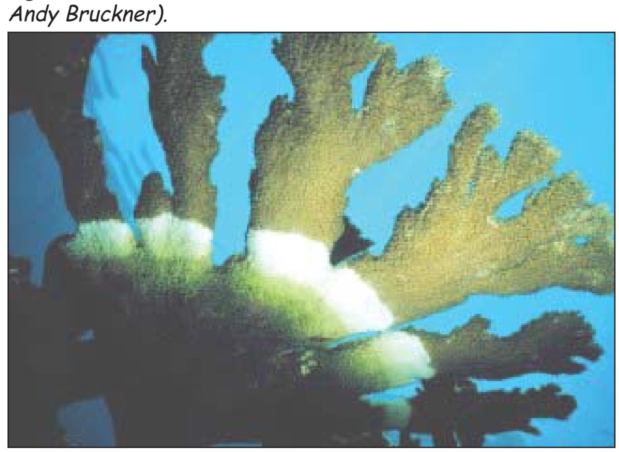
Plague type II and a fungus also affect these reefs. While it does not always advance so quickly, plague type II can progress up to 0.5 cm/day on stony coral. Corals infected with this disease usually do not recover; instead, they die and are overgrown with algae.

Another major impact on USVI coral is bleaching. Major bleaching events occurred in 1987, 1990, and 1998. These affected 16-47% of the corals in any given event or location. Severe coral mortality, however, has not been associated with USVI coral bleaching. Since bleaching is related to increased water temperatures, increased warming should continue to have an effect.

An epidemic in 1983-1984 decimated the long-spined sea urchin, reducing populations as much as 90% around the Caribbean. They are recovering, but slowly. Loss of this herbivore is significant because it feeds on macroscopic algae and plays a major role in reef ecology by keeping algal abundance in check.

Fish and large mobile invertebrates have been affected by human activities. The queen conch

*Figure 77. Elkhorn coral with white-band disease (Photo: Andy Bruckner).*



population abundance is much reduced, from both the loss of habitat and overfishing.

Overfishing has changed the abundance and composition of fish inhabiting USVI reefs. Fisheries are close to collapse; even those within the marine protected areas are deteriorating (Beets 1996, Garrison *et al.* 1998, Wolff 1996, Beets and Rogers in press). According to Beets and Rogers (in press), groupers and snappers are now far less abundant, the proportion of herbivorous fishes has increased, individuals of many fish species are smaller, and spawning aggregations have been decimated.

Accelerated development of uplands, increases in point and non-point discharges, and poor land management impact near-shore water quality and the reef ecosystem. Runoff from the numerous unpaved roads probably contributes the largest amount of sediment to near-shore waters (Anderson and MacDonald 1998). Near-shore habitats, mostly mangroves, salt ponds, and seagrasses have been degraded and in places destroyed from coastal development, contaminant discharges, and sediment-laden runoff. Long-shore turbidity plumes are common after rainstorms.

Some regulations are in place, but current fishing regulations do not provide enough protection. In addition to inadequate enforcement of fishing regulations, regulations for zoning and erosion control are also not fully enforced, with negative consequences for the condition of USVI coral reef ecosystems.

**Condition of FGBNMS Coral Reef Ecosystems** – In the Gulf of Mexico, these well-developed coral reefs are found approximately 192 km south of the Texas/Louisiana border (Fig. 78). These reefs, given federal protection in 1992 and now known as the Flower Garden Banks National Marine Sanctuary (FGBNMS), encompass 56 $mi^2$ (146 $km^2$) of banks and coral reef habitats that were formed atop salt domes on the sea floor. Also part of the FGBNMS, Stetson Bank, a separate claystone/siltstone bank 30 mi away, harbors a low diversity coral community. The East Flower Garden Bank is 25.4 $mi^2$ (65.8 $km^2$) and contains about 247 acres (1 $km^2$) of coral reef. The West Flower Garden Bank is separated from the East Bank by 12 mi and covers about 30 $mi^2$ (77.2 $km^2$), of which 100 acres (0.4 $km^2$) are coral reefs.

The reef platform on the top of both banks is relatively flat with uniform coral growth. The Flower Garden Banks reef platform contains large, closely spaced coral heads. Between groups of coral heads, there are many sand patches and channels. The bank slopes steeply from surrounding deep reef bases to the relatively shallow reef platform. During the time scientists have studied these reefs, coral communities appear stable and in excellent condition. Coral cover (approximately 50%) has not significantly changed (Gittings 1998). Growth rates and other indicators of coral health show similar consistency.

Both disease and bleaching are relatively low. Bleaching only occurs when temperatures exceed 86° F (30° C) and most colonies recover (Dokken *et al.* 1999). Other impacts affecting coral condition are isolated incidences of anchor damage, tow and seismic cables, and illegal fishing gear.

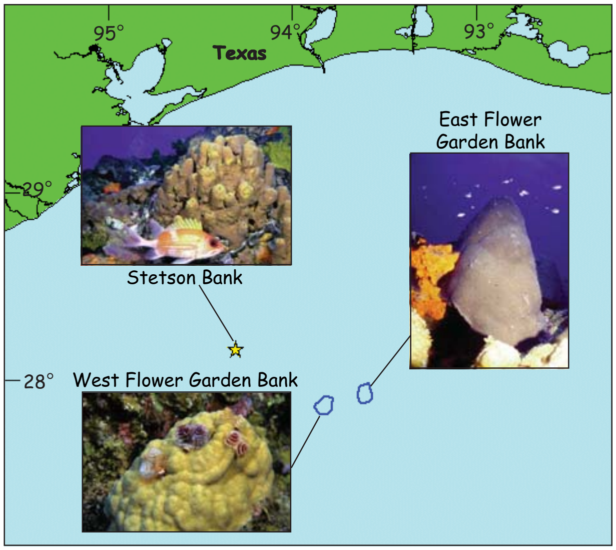



*Figure 78. Map of the Flower Garden Banks National Marine Sanctuary (Photos: Frank and Joyce Burek and Stephen Gittings).*

Algal cover has remained less than 5% in the shallower reef areas. The biggest change in algal cover was associated with the die-off of the long-spined sea urchin in 1983-1984, but cover returned to normal a few years afterward. Along with sponges, algae are a primary component in the deeper waters below 98 ft.

The fish population includes both resident tropical species and migratory pelagic species. Planktivores and benthic invertebrate feeders dominate the 266

Figure 79. Tiger groupers are commercially targeted at the Flower Garden Banks (Photo: Frank and Joyce Burek).

fish species found around the reefs (Pattengill *et al.* 1997). Compared with other reefs in the south Atlantic and Caribbean, fish diversity is low (Pattengill-Semmens 1999).

The impacts of commercial fishing and associated activities are not well known, but fishing pressure is not intense at this time. There is concern that the limited area of hardbottom on and around the Banks do not support current fishing levels. The primary commercial fish species have been snapper and grouper (Fig. 79). While density information for fish has only been available in the last 30 years, anecdotal information suggests a decline of grouper.

There is also evidence that these reefs may serve as an important spawning and aggregation area for certain species of grouper. Targeted fishing, even what is allowed under current regulations, could have a significant impact on these populations.

As with other reefs, anchor damage has occurred on the Flower Garden Banks. Large oil industry vessels, freighters, fishing vessels, (Gittings *et al.* 1992) and foreign-flagged cargo vessels not aware of the restrictions in the area, have all damaged the reefs. The FGBNMS was recently designated the world's first 'No-Anchoring Area' by the International Maritime Organization.

Water quality is good. Salinity and temperature variations are well within the range needed for active coral growth. Turbidity is generally very low (Deslarzes 1998), but there are indicators of some concern. Stable nitrogen isotope analysis indicates coastal pollution is reaching Stetson Bank, and discoloration from turbidity is periodically seen at the Flower Garden Banks.

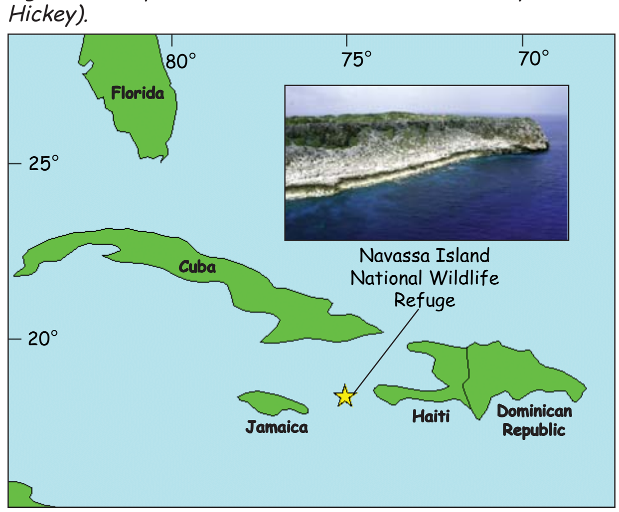
Additionally, oxygen-depleted areas have been identified in a large area of the northern Gulf and may be moving toward the outer Continental Shelf and nearer the Banks.

Primary sources of potential degradation of water quality include coastal runoff and rivers, atmospheric contributions, and effluent discharges from offshore activities such as oil and gas development, and marine transportation (Deslarzes 1998).

**Condition of Navassa Island's Coral Reef Ecosystem** – Navassa is a small 2-mi$^2$ uninhabited U.S. protectorate (since 1857) located between Jamaica and Haiti in the Caribbean (Fig. 80). In 1999, the Secretary of the Interior transferred full administration of Navassa to the USFWS. The Navassa Island Wildlife Refuge is managed as a remote unit of the Caribbean Islands National Wildlife Refuge, including the island and submerged lands out 12 miles offshore by statute. Entry into the refuge is by permit only; however subsistence fishing is allowed.

The cliffs that surround the island are vertical, extending straight down to a largely sand-rubble shelf at about 75 ft, where there is dispersed patch-reef habitat. The nearly vertical reefs at depths less than 75 ft have high live coral cover (20-26%) and a high degree of architectural complexity that makes these reefs particularly valuable as reef fish habitat. Besides scleractinian corals, sponges (7-27%) and fleshy brown macroalgae (10-23%, primarily *Dictyota* and *Lobophora* spp.) accounted for most of the remaining reef cover. The long-spined sea urchin, now scarce throughout most of the Caribbean, was moderately abundant (averaging

Figure 80. Map of Navassa Island (Photo: Bob Halley and Don Hickey).



2.9 adults per 98.4 ft (30 m) transect) at all sites.

Despite its remoteness, there is active fishing by Haitians on these reefs, both trap and hook-and-line. Even so, shallow reef fish communities exhibit high density and retain representation by large snapper, grouper, and herbivores, which are depleted at nearby Caribbean reefs with high fishing pressure.

Other than possible current-deposited marine debris and anchoring of the artisanal Haitian boats, there is no evidence of degradation of the reefs surrounding this island.

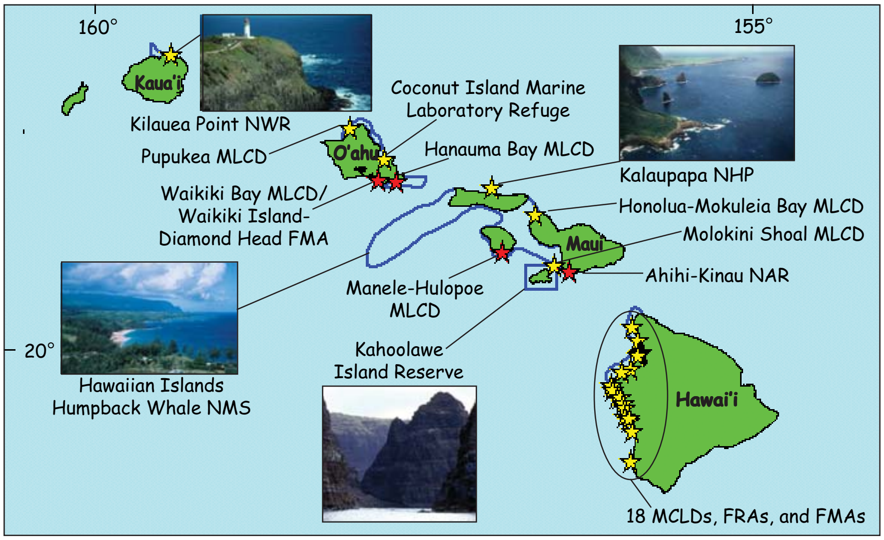



*Figure 81. Map of the Main Hawaiian Islands and their MPAs. Abbreviations: FMA – Fisheries Management Area; FRA – Fish Replenishment Area; MLCD – Marine Life Conservation District; NAR – Natural Area Reserve; NHP – National Historical Park; NMS – National Marine Sanctuary; NWR – National Wildlife Refuge (Photos: Marc Hodges, Barbara Maxfield, Jean Souza, and the NPS).*

**Condition of Hawaiian Coral Reef Ecosystems** – The Hawaiian Archipelago, roughly 1,296 nmi (2,960 km) in length, straddles the Tropic of Cancer in the north central Pacific Ocean along a northwest-southeast axis. The Archipelago consists of eight large islands to the southeast (the Main Hawaiian Islands – MHI) and 124 small islands, reefs, and shoals to the northwest (the Northwestern Hawaiian Islands – NWHI).

Reef habitats progress from individual coral heads colonizing geologically recent basalt substrates to complex reef habitats off sand-covered atolls and in protected lagoons. For waters less than 300 ft, Hunter (1995) estimated a total coral reef area of 979 mi$^2$ (2,536 km$^2$) for the MHI and 4,461 mi$^2$ (11,554 km$^2$) for the NWHI. These values could change significantly when the shallow-water coral reef ecosystem is characterized and mapped.

Main Hawaiian Islands – The MHI are high volcanic islands. They range in age from seven million years old (Kaua'i Island) to less than a day on the eastern side of the island of Hawai'i where molten lava continues to solidify into basaltic rock. Around the islands are non-structural reef communities, fringing reefs, and two barrier reefs (Fig. 81). Recent partial analysis of data by the Hawai'i Coral Reef Assessment and Monitoring Program suggest live coral cover averages around 18%, ranging between 4-50%, at over 30 sites surveyed.

Despite changes in coastal land use, the consensus of many ecologists is that, with a few exceptions, the health of the near-shore reefs around the MHI remains relatively good. As with most reefs near populated areas, reefs in the MHI suffer from degradation resulting from human population growth, urbanization, and coastal development[83].

This is reflected in the health of the organisms that make up the reefs and the plants and animals living around them. General necroses (lesions) and abnormal growth (tumors) are relatively common coral diseases (Hunter 1999).

No major coral bleaching was observed in Hawai'i during the 1997-1998 bleaching event. Currently, this is not a major concern.

The majority of food fish and invertebrates in the MHI are overfished (Shomura 1987, Harman and Kitakaru 1988). Fishing pressure in heavily populated areas of the MHI appears to exceed the capacity of these resources to sustain themselves (Smith 1993). The abundance of reef fish in unprotected areas is substantially lower than areas where fishing is prohibited (Grigg 1994).

A wide variety of Hawaiian invertebrates are currently harvested for the marine aquarium trade. The harvest of live sessile benthic invertebrates,

[83] Ocean outfalls, urban construction, and coastal recreational complexes (e.g., hotels, golf courses) are major sources of reef degradation (Jokiel and Cox 1996).

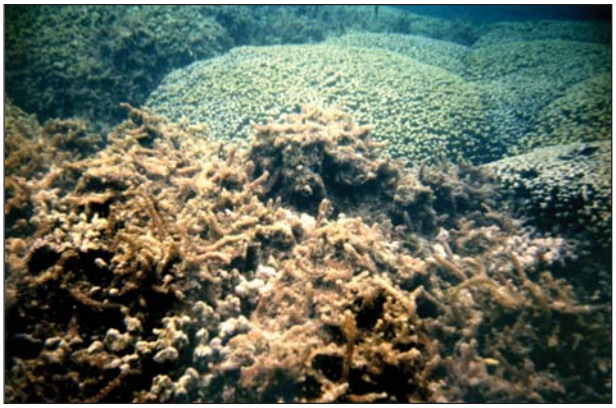


*Figure 82. Alien algae overgrowing corals in Kane'ohe Bay, Hawai'i (Photo: Donna Turgeon).*

especially the featherduster worm (*Sabellastarte sanctijosephi*), for the aquarium trade often causes destruction of reef habitat during collection.

Increasingly, alien species are a problem. Alien seaweeds are invading coral reefs, rocky shores, tidepools, and sandy beaches (Staples and Cowie 2001, Fig. 82). Thickets of mangroves not native to the Islands are forming along sheltered bays, ponds, and inlets, frequently overgrowing traditional Hawaiian fishponds, mudflats, and inshore reef flats. Many alien fish species, intentionally introduced, have established viable populations and, in some cases, are thriving. Over 250 species of invertebrates have also been introduced, but so far there is no documented evidence of their effect on coral.

Hawaiian green sea turtles have shown a dramatic increase in tumors, a condition almost unknown 15 years ago (Fig. 83).

Most MHI shallow-water coral reefs are extremely close to the majority of the State's 1.2 million humans – within a mile from major coastal urbanization and development (Fig. 84). This makes them prone to pollution. For example, secondary-treated sewage from urban areas is discharged primarily through deepwater outfalls on O'ahu and through injection wells on Maui and Hawai'i (Kona District). Nutrient leaching from injection wells on Maui is attributed to the algal blooms occurring there.

Sediment runoff in the MHI has been estimated at more than a million tons per year from agricultural, ranching, urban, and industrial activities (USFWS in Green 1997a). Livestock grazing and agriculture have been the predominant land uses for over 100 years on O'ahu, Maui, Moloka'i, and Lana'i, contributing to chronic erosion and sedimentation on fringing reefs. Further, reef habitat has been lost to dredging and filling near-shore reefs.

*Figure 83. Turtle with large tumors (Photo: Ursula Keuper-Bennett and Peter Bennett).*

A number of recent shore-based chemical spills from industrial and aquaculture (Clark and Gulko 1999) in the MHI have put large amounts of sulfuric acid, PCBs, and refrigerants onto near-shore reefs. On top of that, the USCG has recorded a 200% increase in oil spills from 1980 to 1990 (Pfund 1992).

High concentrations of dieldrin and chlordane were found in oyster tissues sampled near stream

*Figure 84. Honolulu is located near two marine protected areas with coral reefs (Photo: Donna Turgeon).*

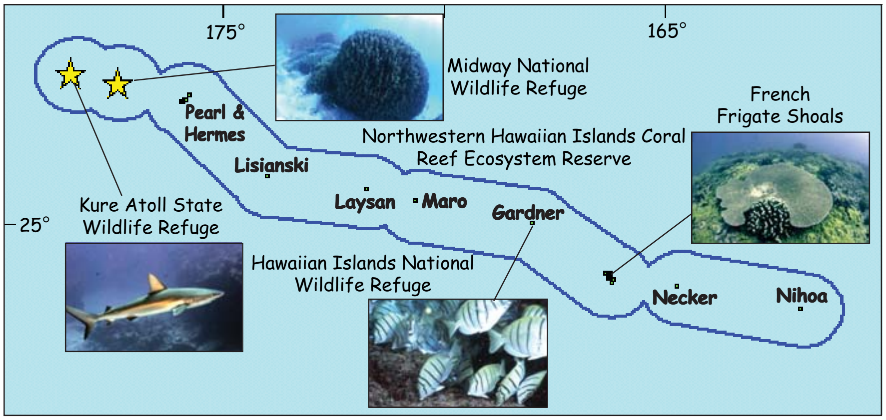



*Figure 85. Map of the NWHI and its MPAs (Photos: James Maragos).*

mouths in Kane‘ohe Bay in 1991, five years after the ban on pesticides went into effect. Elevated levels of lead, copper, chromium, and zinc have been found in a number of tissue samples, particularly near the southern, more urbanized, watersheds of the bay (Hunter *et al.* 1995).

Northwestern Hawaiian Islands – Among 124 small islands, reefs, and shoals, the NWHI has 10 primary, mostly uninhabited, atolls and islands and 30 submerged banks. The NWHI extend more than 1,300 nmi to the northwest of the island of Kaua‘i from Nihoa to Kure Atoll (Fig. 85).

Recent research found coral cover high off many atolls (Maragos and Gulko 2002, J. Parrish and J. Maragos pers. comm.), and at Neva Shoals near Lisianski Island (R. Brainard pers. comm.).

In general, the NWHI reef ecosystem is in excellent condition. While there is little information on coral disease and infections, observed disease was low during 2000-2001 surveys. There is even less information on diseases for other reef species. No turtles with tumors have yet been observed in the NWHI. Since fishing and other human impacts are relatively limited, these reefs are among the few remaining large-scale, intact, predator-dominated reef ecosystems anywhere (Friedlander and DeMartini 2002).

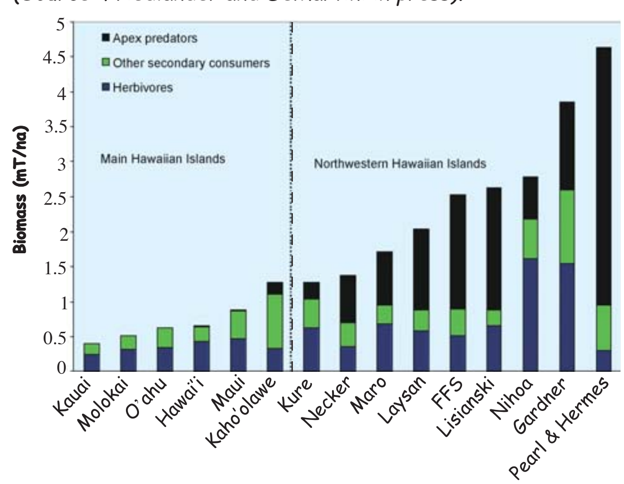
Surveys in the mid-1970s, 1980s, and 1990s found the coral reef fish community to be dominated by carnivores[84]. The latest study (Friedlander and DeMartini 2002) found more than 54% of the total fish biomass consists of apex predators[85], followed by herbivores (28%), lower-level carnivores (18%), and an assortment of small-bodied species (Fig. 86).

Prized fish species tend to be larger and more abundant compared to populated areas of the MHI (Okamoto and Kawamoto 1980, Hobson 1984, Parrish *et al.* 1985). More quantitative studies at French Frigate Shoals and Midway Atoll documented biomass estimates of non-apex carnivorous and herbivorous fishes on shallow reefs almost twice that of the MHI, probably reflecting differences in fishing pressure (DeMartini *et al.* 1996).

The commercial lobster fishery is closed throughout the NWHI. Fishing for the black-lipped pearl oyster closed after only a couple years because of concerns for the harvest sustainability of this stock.

Alien species were not conspicuous in the NWHI during 2000-2001 surveys. The majority of alien species have been reported at Midway Atoll (L. Eldredge pers. comm.), most likely arriving there attached to the hulls of the ships docked in the harbor. Midway National Wildlife Refuge is a former U.S. Navy Base, the only island in the NWHI that had an active public use program[86]. Since the 1940s, Midway Atoll has had an active port and airstrip used for bringing supplies and tourists from the MHI and other areas.

*Figure 86. Biomass of reef fishes in the MHI and the NWHI (Source: Friedlander and DeMartini in press).*




[84] Mostly jacks, sharks, goatfishes, scorpionfishes, bigeyes, and squirrelfishes.
[85] Primary apex predators were the sharks and jacks; the herbivores were mostly parrotfishes and surgeonfishes.
[86] The public use program at Midway National Wildlife Refuge was temporarily suspended in December 2001, but the USFWS remains committed to appropriate public use as soon as possible.

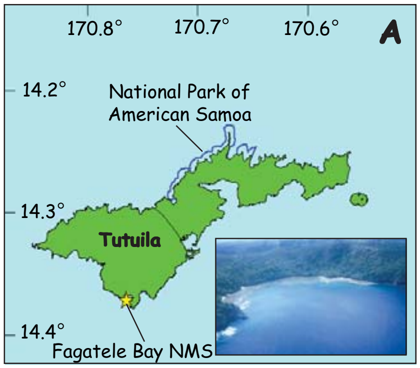



*Figure 87A. Tutuila Island and its MPAs. Abbreviation: NMS – National Marine Sanctuary (Photo: Fagatele Bay NMS).*

High levels of toxic contaminants have been reported from wildlife tissues and from sediments collected at several near-shore sites in the NWHI. PCBs have been measured both in Hawaiian monk seal blood and blubber, moray eels, and albatrosses (Tummon 2000, L. Woodward pers. comm.). The analysis of 36 sediment samples for over 100 toxic contaminants (Turgeon in Maragos and Gulko 2002) revealed unexpectedly high concentrations of a few chemicals[87] from NWHI sediments.

**Condition of American Samoa's Coral Reef Ecosystems –** There are five volcanic islands and two atolls that make up American Samoa (Fig. 87a-c). Located in the central South Pacific Ocean, the islands are small, the largest being 55 mi$^2$ (Tutuila). The islands are steep, sometimes reaching over 2,500 ft within one mile from shore. Fringing reefs predominate. The total area of coral reefs within the 328 ft (100 m) bathymetric line has been calculated as 114 mi$^2$ (296 km$^2$) (Hunter 1995). Mapping of American Samoa's reef ecosystem will begin in 2003.

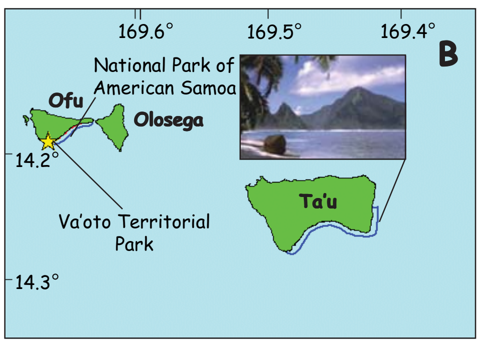



*Figure 87B. Islands of the Manua Group and their MPAs (Photo: Chris Stein).*

In the past 20 years, between hurricanes, a crown-of-thorns starfish invasion, a period of warmer than usual seawater temperatures, and coral bleaching, the reef ecosystem has been fairly stressed. In some places, there have also been chronic human impacts. But by 1995, the corals were beginning to recover, and now some reefs are considered 'recovered' (C. Birkeland pers. comm.). Removing a number of shipwrecks and banning live rock collection for aquariums has also helped.

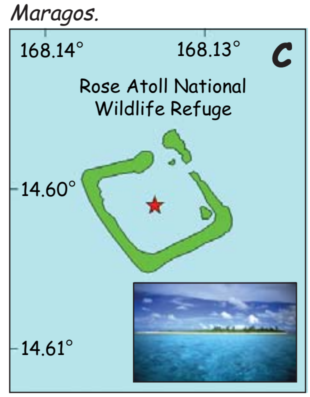
Macroalgal cover is generally low around the islands, indicating that available nutrient concentrations may be relatively low, hervbivore grazing may be high, or both. Low nutrients could be the result of the constant ocean flushing that keeps the waters clear and prevents nutrient buildup. Encrusting coralline algal (*Porolithon*) cover is high (40-50%) helping to cement and stabilize the loose surface below (Birkeland *et al.* 1997).

While the coral community may be recovering nicely from adverse natural and man-made events, recovery by fish and invertebrates has been slower. A number of commercially desirable species have been overfished. Harvested species such as giant clams and parrotfish are overfished in American Samoan near-shore waters, and there is heavy fishing pressure on surgeonfish (Craig *et al.* 1997, Page 1998, Green and Craig 1999). Many village fishermen and elders are convinced there are fewer and smaller groupers, snappers, and jacks than there were just a few decades ago (Tuilagi and Green 1995). A recently imposed territorial ban on SCUBA fishing should help this situation.

The endangered hawksbill sea turtle is rapidly approaching extinction in the Pacific (Eckert *et al.* 1998). The population of these turtles that nest on American Samoan reefs has seriously declined from illegal harvesting and loss of nesting habitat (Tuato'o *et al.* 1993).

Water quality throughout the islands is generally good except for three things: turbid water and sedimentation, nutrient enrichment, and toxic contaminants within the harbor. Fish tissues and substrates collected from Pago Pago Harbor have been reported with above ambient levels of heavy metals and other chemicals (AECOS 1991). Until the early 1990s, nutrient loading from cannery wastes in the inner harbor caused

*Figure 87C. Rose Atoll and its MPA. A no-take reserve area is marked in red (Photo: Jim Maragos.*




[87] ∑DDTs, ∑PCBs, ∑PAHs, arsenic, copper, and nickel were above the 85th percentile of all sediments monitored by the NOAA National Status and Trends Program. The ∑ symbol indicates similar toxic organic chemicals have been grouped together.

perpetual algal blooms and occasional fish kills due to oxygen depletion. Since then, canneries have been required to dispose of wastes beyond the inner harbor, so nutrient loading has generally decreased.

**Condition of Guam's Coral Reef Ecosystems** – A U.S. territory, and the southernmost and largest island in the Mariana Archipelago, Guam is 216 $mi^2$ and has a maximum elevation of 1,330 ft (Fig. 88). The northern half of the island is relatively flat and consists of uplifted limestone; the south is primarily volcanic, more rugged and with large areas of erosion-prone lateritic soils.

The island has fringing, patch, submerged, and barrier reefs, along with offshore banks. The fringing reef flats vary from 30 ft wide on the windward side to well over 300 ft elsewhere. The combined area of coral reef and lagoon is approximately 27 $mi^2$ (69 $km^2$) in nearshore waters between 0-3 mi, and an additional 42 $mi^2$ (110 $km^2$) in federal waters greater than 3 mi offshore (Hunter 1995). Guam lies close to the center of high coral reef biodiversity in the western Pacific. Right in the middle of the tropical Pacific typhoon belt, it averages one substantial typhoon each year. Shallow-water coral reefs play a major role in protecting the land from storm waves.

In general, the condition of Guam's coastal reefs continues to decline, primarily as a result of land-based activities. There is evidence of an overall decline in coral species diversity over the past 30 years. Coral recruitment data also support the observations (Fig. 89). In a little over 10 years, recruitment dropped significantly. Increases in blue-green algae (overgrowing corals), junenile

Figure 89. Coral spawning (Photo: Robert Richmond).

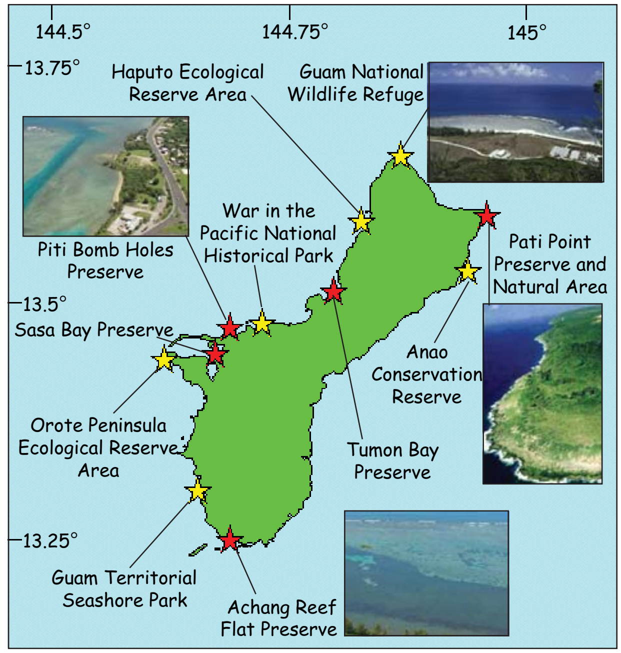



*Figure 88. Map of Guam and its MPAs (Photos: USFWS, Jay Gutierrez, and Danko Taborosi).*

crown-of-thorns starfish, coral diseases, the dark gray to black encrusting sponge (*Terpios hoshioto*), and coralline algal lethal orange disease have all been observed on Guam's reefs. None seem to be at a critical level at this time. However, each can have a major impact on these reefs.

Statistics collected by the Guam Department of Agriculture's Division of Aquatic and Wildlife Resources indicate fish populations and catch-per-unit-effort (DWAR) have declined over the past 15 years. Total finfish harvest between 1985 and 1999 dropped almost 60%. Catch-per-unit effort has dropped and large reef fish are rare. Fishing practices, including the use of unattended gill nets, the use of bleach to stun and capture live fish, SCUBA spearfishing, and fish traps have contributed to the problem. However, habitat loss due to sedimentation, pollution, and physical damage has also been responsible for reduced fish populations. Regulations and protected reserves are being enforced to deal with this problem.

Reefs impacted by natural disturbances, including typhoons, crown-of-thorns outbreaks, and earthquakes are not recovering in specific areas. The condition of local reefs is variable, ranging from excellent to poor, depending on adjacent land use, accessibility, location of ocean outfalls and river discharges, recreational pressure, and circulation patterns. Coral cover on the good-to-excellent reefs

*Figure 90. Urban development around Agana Bay. Adjacent coral reefs can be seen in the lower right-hand corner of the photograph (Photo: Guam DAWR).*

ranges from 35-70%, while the most damaged sites have less than 10% coral cover, with fleshy algae and sediment dominating.

Guam's northern reefs are generally in better condition because there is limited erosion and sedimentation from the limestone landmass (no surface rivers or streams), but there is some aquifer discharge and associated eutrophication damaging the reefs. Coral cover and diversity are generally highest on the northeastern, windward exposures.

Most of the fringing reefs off the southern and southwestern shores remain in fair-to-poor condition. Clay sediments and freshwater runoff heavily influence reefs off the eastern, central, and southern sides of the island during the rainy season. During the early 1990s, a road project in the south resulted in particularly heavy sedimentation on the fringing reefs and high coral mortality. The sediment accumulation on reefs has been documented to substantially reduce coral diversity and abundance (Randall and Birkeland 1978b).

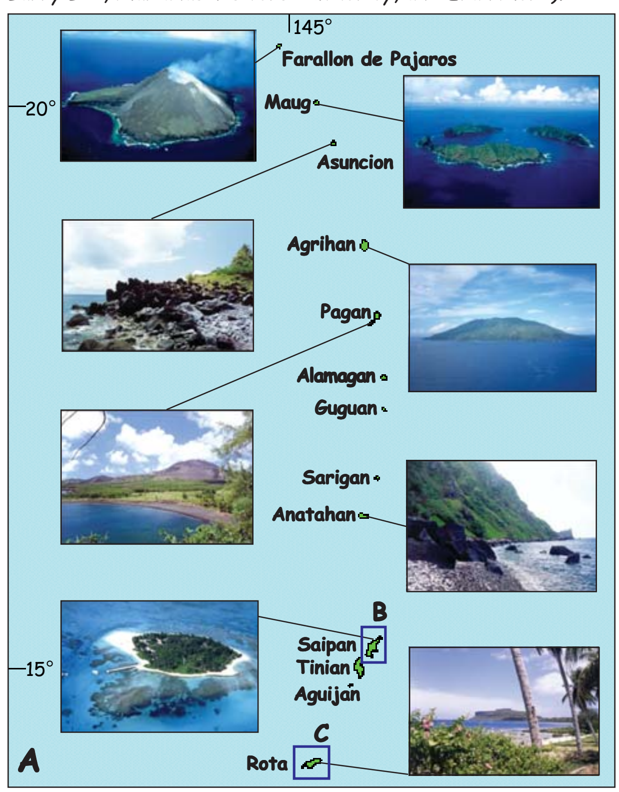
Corals in the inner areas of Agana, Tumon, and Piti Bays, centers of tourism and recreation activities, are in relatively poor condition, affected by discharges from land and the impacts of recreational activities (Fig. 90). A variety of industrial impacts have damaged corals within Apra Harbor, home to a U.S. Navy Base and the commercial port for the island, but fringing and patch reefs near the harbor mouth are in relatively good condition. Pollutants have been found in sediments of Apra Harbor, including PCBs, heavy metals, and PAHs. Toxic pollutants from other human found in the sediments raise concerns over the start of a harbor dredging project.

During periods of heavy rain, the sewage treatment plants divert stormwater mixed with wastewater directly into the ocean, with only primary treatment. Guam's aquifer discharge adds to eutrophication due to leaky sewage pipes, fecal material from animals, decomposing vegetation, and agrochemicals (fertilizers).

Guam's main power plants are located on Cabras Island, in the northern portion of Apra Harbor. Elevated temperatures, caused by the discharge of seawater used to cool the generators, have resulted in coral mortality. The discharge of cleaning chemicals has also occurred, with subsequent negative impacts on local coral populations.

**Condition of CNMI's Coral Reef Ecosystems** – A U.S. territory, the Commonwealth of the Northern Mariana Islands (CNMI) is a chain of 14 islands located in the Marianas Archipelago in the northwestern Pacific Ocean about 100 nmi northeast of Guam (Fig. 91A-C). The five southern islands are primarily raised limestone and have well-developed fringing coral reefs. The ten largely uninhabited northern islands are mostly volcanic and have less reef development, mainly because

*Figure 91A. Map of CNMI (Photos: Americopters, Inc., Larry Lee, Marianas Visitors Authority, and Eran More).*



they are younger and have steep shorelines.

Barrier reefs and well-developed fringing reefs tend to form along the western coasts of the southern islands, while eastern coasts are rockier with steep cliffs (UNEP/IUCN 1988). Extensive fringing and apron reefs are found on the northern and eastern sides of the island.

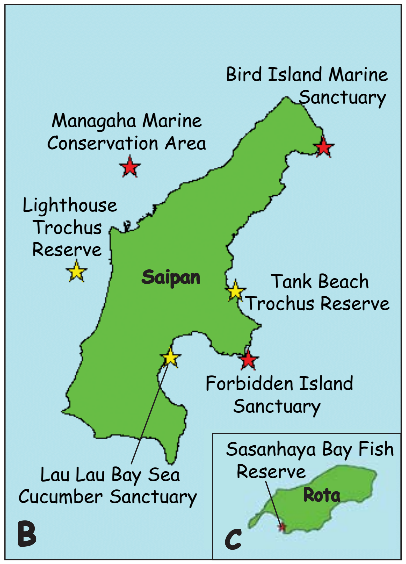



*Figure 91B. and C. Maps of established MPAs on the islands of Saipan and Rota.*

In addition to coral reefs surrounding the main islands, there are a number of submerged seamounts and shoals surrounding the CNMI that are considered reef banks. The total coral reef area in the CNMI has been estimated at 224 mi$^2$ (579 km$^2$, Hunter 1995); but benthic habitats have yet to be mapped. The Hunter estimate is probably high, since it included offshore banks and shoals (M. Trianni pers. comm.).

CNMI reef ecosystems are in good-to-excellent condition. The reefs adjacent to the southern populated islands of Saipan, Tinian, and Rota receive the bulk of human impacts from population growth, coastal development, fishing, and tourism. They are generally the most degraded.

Although coral reefs in the CNMI were spared the impacts of the 1998 coral bleaching event, shallow reefs off the CNMI (less than 10 ft) recently experienced bleaching as deep as 66 ft (1994, 1995, 1997, and 2001). High mortality was only documented for the 2001 event. There has been no quantitative assessment of bleaching effects for any of these events.

The CNMI Marine Monitoring Team is investigating disease incidences and potential impacts of three common diseases infecting CNMI coral reef species: coralline lethal orange disease, tumors, and black-band disease.

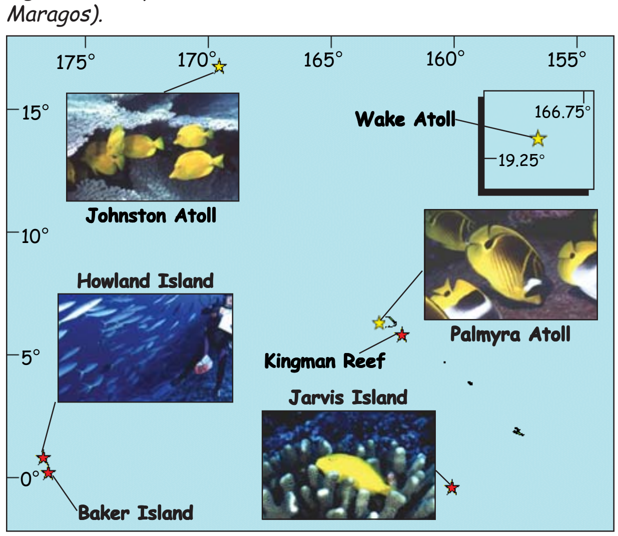
The southern islands experienced a crown-of-thorns outbreak in the late 1960s (Marsh and Tsuda 1973). There were smaller outbreaks associated with coral mortality at some reefs around Saipan in the mid-1980s. Most reefs appear to be recovering. *Terpios hoshinoto* a sponge that can overgrow and kill live coral, is present on CNMI reefs, but is not currently a major problem.

Reefs off southern populated islands are all overfished at some level. The local people consider the northern reefs relatively pristine because the population is low there. Some analyses of old data show catch from spearfishing and SCUBA off Tinian were smaller and had a lower catch-per-unit-effort (M. Trianni pers. comm.).

The impact of pollution sources on marine water quality in general, and coral reef resources in particular, is not well quantified. Sedimentation and turbidity impacts the water quality of all three southern islands and several of the high northern islands, yet little quantitative data on sedimentation has been collected. After periods of heavy rain, sediment washes down unpaved secondary roads on the three southern islands, creating sediment plumes that degrade near-shore water quality. Some major construction projects are reported to have increased sediment in local waters.

Increased nutrients impact reefs adjacent to populated southern islands and several northern islands because of feral goats. The CNMI Division of

*Figure 92. Map of Pacific Remote Insular Reefs (Photos: Jim Maragos).*



Environmental Quality monitors microbial violations most likely associated with runoff from septic/sewage systems and animal waste.

| Location | Protected Submerged Lands ($km^2$) | Coral Reef Habitat ($km^2$) * |
|---|---|---|
| Baker Island | 123 | 12 |
| Howland Island | 130 | 8 |
| Jarvis Island | 143 | 7 |
| Johnston Atoll | 480 | 239 |
| Kingman Reef | 1,957 | 105 |
| Palmyra Atoll | 2,085 | 65 |
| Wake Atoll** | Not available | 32 |
| **Total** | **4,918** | **468** |

*Table 3. Coral reef area on the Pacific Remote Insular Reefs (Source: S. White pers. comm.). *Within protected submerged lands; **Data from Hunter 1995.*

**Condition of U.S. Pacific Remote Insular Reef Ecosystems**[88] – In addition to the Midway, Hawaiian Islands, and Rose Atoll National Wildlife Refuges (NWR) covered elsewhere in this report, the USFWS administers six other remote NWRs[89] in the Pacific Region (Fig. 92). Johnston Atoll is located 800 nmi (1,500 km) southwest of Honolulu and is under joint USFWS and Department of Defense (DoD) management. Howland, Baker, and Jarvis Islands are low equatorial, arid coral islands. Howland and Baker are in the Phoenix Islands, about 1,620 nmi (3,000 km) southwest of Hawai‘i. Jarvisis is 1,350 nmi (2,500 km) south of Hawai‘i in the Line Islands. All three are surrounded by narrow fringing reefs. Kingman Reef and Palmyra Atoll are the northernmost of the Line Islands, at about 1,000 nmi (1,500 km) southwest of Honolulu. Wake Atoll is the only U.S. remote island that is not an NWR, and is co-administered by the DoI and DoD. It is the northernmost of the Marshall Islands, about 1,620 nmi (3,000 km) west of Hawai‘i, and the northernmost of the U.S. atolls located 270 nmi (500 km) north of Bokaak Atoll.

The area covered by coral reefs around these islands is given in Table 3, using official USFWS records based on the 100-fathom bathymetric line of refuge boundaries (S. White pers. comm.). The estimates total 181 mi$^2$ (468 km$^2$), differing significantly from the 274 mi$^2$ (709 km$^2$) estimated for these same areas by Hunter (1995).

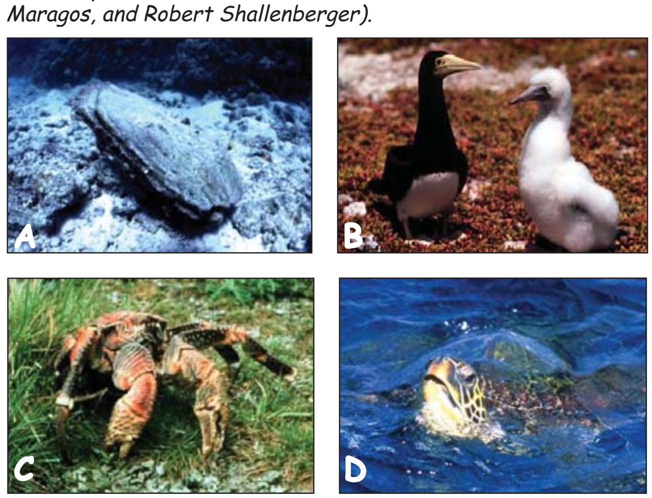
All the coral reefs are generally in excellent-to-good condition. In 2000-2002, NOAA and the USFWS co-sponsored three expeditions to Howland, Baker, Jarvis, Kingman, and Palmyra, and completed the first-ever detailed marine biological survey of these islands. Due to their small size and geographic isolation, Jarvis, Johnston, and Wake support about 40 species of stony corals. Howland and Baker Islands have 80-90 stony coral species each because they are further to the west where species biodiversity is greater. Kingman and Palmyra Atolls have the highest diversity (140-155 species) because they are large atolls with more reef area and greater habitat variety (Fig. 93). Seasonally, the Equatorial Countercurrent flows past, providing them with the larvae of species from western reefs, in addition to larvae coming from the east during other seasons when the North and South Equatorial Currents flow past the reefs.

Coral bleaching has killed corals and affected reefs at most of the equatorial islands within the past five years – Howland, Baker, Jarvis, Palmyra, and likely Kingman (J. Maragos pers. comm.).

The remote NWRs are fully protected by no-take provisions, except for Johnston and Palmyra where catch-and-release fishing is allowed. Invertebrate and finfish populations are in excellent condition. Fish and other wildlife may be as undisturbed as they were thousands of years ago, although there is evidence of recent unauthorized shark fishing at most islands except Jarvis and Wake (J. Maragos and P. Lobel pers. comm.).

Water quality is not an issue since all of the atolls and islands are at least 150-1,000 miles from any population center.

*Figure 93. A. Pearl oysters. B. brown boobies. C. coconut crabs. D. green sea turtles. All are threatened species protected by the Palmyra Atoll NWR (Photos: Stan Butler, Beth Flint, Jim Maragos, and Robert Shallenberger).*




[88] Much of the information in this section on U.S. Pacific Remote Insular Reefs was provided by J. Maragos (pers. comm.).

**Condition of the Pacific Freely Associated States** – These nations are the Republic of the Marshall Islands (RMI or Marshalls), the Federated States of Micronesia (FSM), and the Republic of Palau (Palau). These Indo-Pacific countries became independent from the United States 15-25 years ago, but maintain strong political and economic ties.

The FSM and Palau are known as the Caroline Islands. Over 1,553 miles (2,500 km) in length, they are one of the longest island chains. Each island group has its own language, customs, local government, and reef tenure system.

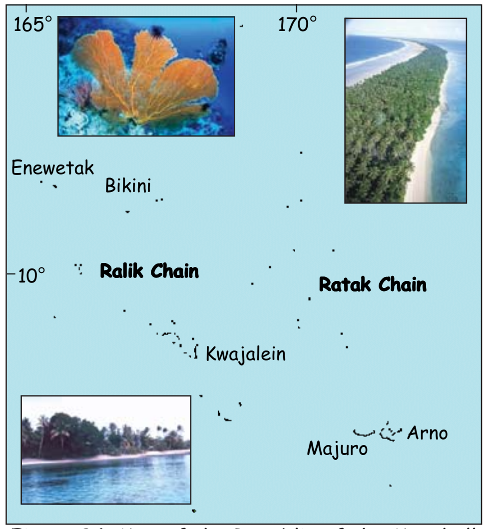


*Figure 94. Map of the Republic of the Marshall Islands (Photos: James McVey and the RMI Embassy).*

Republic of the Marshall Islands – The RMI has 1,225 islands with a land mass less than 0.01% of its total 749,800 $mi^2$ ocean area (1,942,000 $km^2$, Fig. 94). Islands range from tiny, barely emergent islets to Kwajalein, the world's largest atoll (about 6 $mi^2$ of dry land with an 839 $mi^2$ lagoon). Some islands have significant rainfall, but many in the north have little or, in dry years, no rain. Typhoons are rare.

Despite the 67 nuclear tests detonated between 1946 and 1958, the reefs overall are in good condition (National Biodiversity Team of the Marshall Islands 2000). Even reefs used for testing have recovered well, though perhaps not as completely as some observers have reported recently.

There is little data on the diversity of coral and related organisms. Many early RMI assessments were trying to determine impacts of nuclear testing. Recently though, some independent surveys have been done. Fish diversity appears to be relatively high, with a number of species endemic to either the Marshalls or nearby areas.

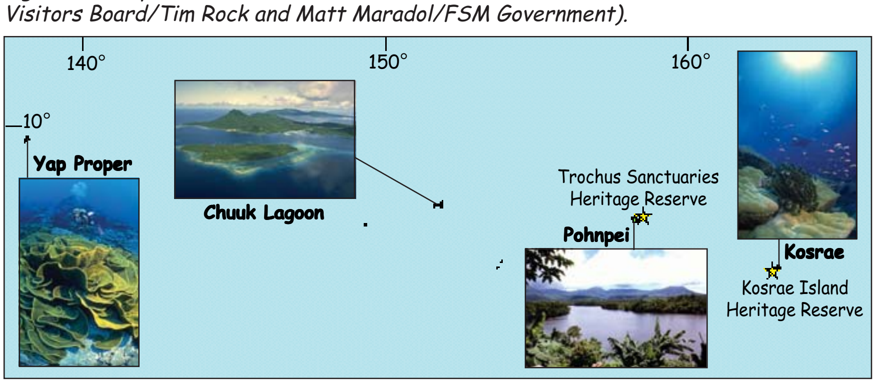
Besides historical nuclear activity, the usual human-induced stresses occur – boat anchoring, fishing gear damage, and occasional ship groundings with resulting fuel spills, and trash and waste in the water.

With low elevation (atolls and low coral islands have an average elevation of 7 ft), some or all of the Marshall Islands could be submerged if climate change moderately raises the sea level. Further, with warmer temperatures, shallow-water reef-building corals could be impacted. A temperature increase of even 1.8° F (1° C) could cause coral mortalities and affect overall reef growth.

While most of the obvious effects of the nuclear tests are gone, there are other potential impacts. Long-lived radionuclides in the fine sediments of the lagoon bottoms are yet a concern for marine ecosystem food chains. While reports state the fish are again safe to eat, the physiological impacts of radiation on the genetic material of all the organisms, particularly to the humans that may have eaten those fish, has not been determined yet.

The Federated States of Micronesia – The FSM has four states (Kosrae, Pohnpei, Chuuk, and Yap, Fig. 95). Each state supports population centers on high volcanic islands. FSM has both high islands and low atolls. The people of FSM have a strong dependence on coral reefs and marine resources, both economically and culturally.

*Figure 95. Map of the Federated States of Micronesia and its MPAs (Photos: FSM Visitors Board/Tim Rock and Matt Maradol/FSM Government).*




Reefs in the FSM are generally in good shape. As with other high volcanic islands,

[89] Howland Island National Wildlife Refuge, Baker Island National Wildlife Refuge, Jarvis Island National Wildlife Refuge, Palmyra Atoll National Wildlife Refuge, Kingman Reef National Wildlife Refuge, and Johnston Atoll National Wildlife Refuge.

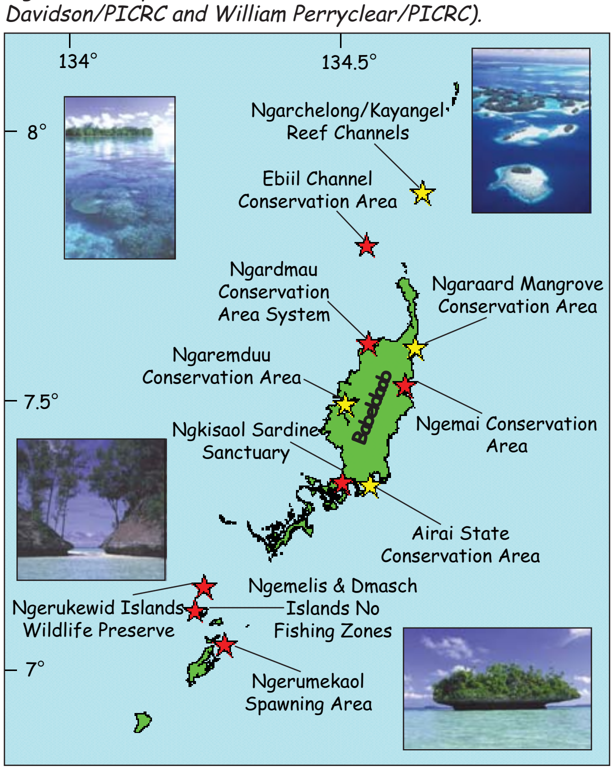
coastal development and agriculture often brings siltation, turbidity and other water quality concerns. Some degradation of reef ecosystems has already occurred in the more populated areas, and is expected to increase. Several large development projects, such as construction of an airport and a deep draft harbor, have had significant impacts on local reefs. Reefs located near population centers, within harbors, and near shipping lanes have had the largest impacts from fishing and ship groundings. Wrecks have caused local damage to both reef structures and biota.

Quantitative assessments of fisheries resources are limited, but some market information suggests fishing may be substantial and reef fish around some islands may be over-exploited. Overfishing has been documented as a result of foreign commercial activities. There have been destructive fishing practices, including the use of explosives to capture reef fish.

The Republic of Palau – Palau is a separate sub-archipelago at the western end of the Caroline Islands (Fig. 96). It lies about 460 mi (741 km) east of Mindanao in the southern Philippines and 810 mi (1,300 km) southwest of Guam.

There are about 20 main islands and over 500 small islands in the 435-mi (700-km) chain of

*Figure 96. Map of Palau and its MPAs (Photos: Kevin Davidson/PICRC and William Perryclear/PICRC).*




islands. The islands are volcanic, atolls, raised limestone, and low coral islands. Most of the population resides on several large volcanic islands; Koror is the capital.

Along the western coast of Palau, there is a long, well-developed barrier reef protecting the main cluster of islands. The reef on the eastern side is not as well developed, and some areas do not have any barrier reefs. There are more extensive reefs in the Southern Lagoon, with gaps and passes into the lagoon on the eastern side.

Within the whole Indo-Pacific region, Palau's coral diversity approaches the highest diversity of the Philippines, Indonesia, and Australia. The reefs closest to population centers or development show signs of degradation. Prior to the 1998 coral bleaching event, remote reefs were generally healthy with coral cover that ranged from 10% to over 70%.

The 1998 bleaching event affected shallow-water corals throughout much of Palau. Almost all reefs were bleached and have not yet recovered. Crown-of-thorns starfish are preying on the few surviving *Acropora* (J. Maragos pers. comm.). Overfishing around more populated areas is apparent, with a lack of or low abundance of desirable species. This is particularly true when data are compared to the Southwest Islands, but the ocean slopes still support abundant reef fish populations.

Even after the Rock Islands were designated as an MPA to protect nesting sites of the hawksbill turtle, poaching of eggs and taking turtle shell for jewelry has kept the nesting activity low.

There are no major water quality problems in the atolls. Coastal pollution, sedimentation, and erosion are still relatively nonexistent. The high, populated islands have local areas with degraded water quality. With heavy rainfall and steep topography, erosion and sedimentation rates can be high. Upland clearing of forested areas for agriculture has resulted in landslides and runoff,with sediment plumes impacting coastal resources.

## National Trends in Coral Reef Ecosystems

There is relatively little quantitative information available for assessments of temporal or spatial trends in ecosystem condition at this time.

**Temporal Trends** – For most regions, quantitative measures of most indicators of reef condition (e.g.,

[90] Indicators of reef ecosystem health such as mortality rates and larval recruitment of corals and fisheries.

disease vectors, the extent of infection and the resulting mortality rates, and the loss of live reef cover) are generally lacking, so temporal trends could not be compared across the entire United States and the Freely Associated States.

In places where there has been credible long-term monitoring there are alarming temporal trends. For example, the FKNMS has recorded a general decrease in coral cover and harvested species over the last five years. On the other hand, monitoring of FKNMS fully protected areas over the same time period shows an increase in previously harvested fish and lobster populations – animals are larger and more abundant (Fig. 97). Monitoring of other no-take reserves show the same trend.

*Figure 97. Yellow-tail snapper is a harvested species that has benefited from the no-take areas in the FKNMS (Photo: FKNMS).*

Over the past 20 years, there seems to be irrefuable evidence of an increase in disease and mortality of corals and other invertebrates on reef systems off Florida, Puerto Rico, and the USVI.

There is a pervasive long-term trend of overfishing harvested species at most reef systems where there are large populations living nearby. A number of reef fish species have been listed as threatened or endangered under the U.S. Endangered Species Act. Where reef habitat has been lost or the ecosystem substantially degraded, it may be difficult to reverse declining population trends for the rare species despite conservation measures.

Because of over-harvesting of adults and their eggs and loss of nesting habitats, all sea turtles are listed as endangered or threatened by extinction as a species.

Of the 27 species of marine mammals identified from coral reef ecosystems of the United States and the Freely Associated States, 21 are endangered or threatened. The endangered Hawaiian monk seal, usually found only in the Northwestern Hawaiian Islands, is occasionally sighted in the Main Hawaiian Islands. The Caribbean monk seal (*Monachus tropicalis*), is listed as endangered, but is probably extinct.

**Spatial Trends in Ecosystem Condition** – The next seven tables present information assessing spatial trends in coral reef ecosystem condition within the United States and Pacific Freely Associated States. Because this is the first report and the beginning of a comprehensive assessment and monitoring program, some data are missing; in other places, only ranges and estimates were available.

The information in these tables will form the basis for determining spatial trends in ecosystem condition in subsequent biennial reports. These tables compare total area of coral reef, delineate reef-associated habitats (e.g., seagrass and macroalgae), and characterize the type and abundance of species within those habitats.

Until all the data gaps are identified and a comparable, coordinated monitoring program fills the most critical gaps, it will be impossible to compare regions with confidence. Available data were used for this report, so much of the data in these tables only provide estimates, and there are gaps where no literature estimates were available.

To fill the gaps and build a National Mapping and Monitoring Network, NOAA held two workshops in FY02 and reached a consensus on protocols among the managers and scientists monitoring coral reef health. The workshops were the beginning of building a nationally-coordinated program with comparable monitoring methods so managers can share data and assess the condition of each jurisdiction's coral reef ecosystems. It was also the start of the development of a 'report card' or rating system for tracking coral reef ecosystem change for future reports. Without quantitative and comparative monitoring data, the ability to develop cross-region indicators for reporting is seriously limited.

The criteria for evaluating reef condition, the **health indices**[90] and the **metrics**[91] for ranking have

[91] Measurements of selected indicators used to track changes. For example, developing a fish consumption guideline would be an excellent metric for toxic contaminants. It would indicate how many fish would be safe to consume in a year because of toxic contaminant tissue burdens. As this metric changed, the index of whether the fish of a given reef were safe to eat should be an item of interest to residents and tourists alike.

| | Florida | Puerto Rico | US Virgin Islands | Flower Gardens | Main Hawaiian Islands | Northwestern Hawaiian Islands | American Samoa | Guam | Northern Mariana Islands | U.S. Remote Insular Reefs | Marshall Islands | Federated States of Micronesia | Palau |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Atolls | | | | | √ | √ | √ | | | √ | √ | √ | √ |
| Barrier reefs | √ | √ | √ | | √ | | | √ | √ | | | √ | √ |
| Fringing reefs | √ | √ | √ | | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| Patch reefs | √ | √ | √ | | √ | √ | | √ | √ | √ | √ | | √ |
| Offshore bank reefs | √ | | | √ | √ | √ | √ | √ | √ | | √ | | |
| Associated unique reefs | W/ S | | | F/ S | | A/ M | | | | √ | | | |

*Key: A—Ancient reef F—Fire coral reef M—Mollusk reef S—Sponge reef W—Worm reef*

Table 4. Types of reefs found in the United States and the Freely Associated States (Photo: Richard Mieremet).

yet to be developed. Quantitative information crucial to developing health indices for coral reef ecosystems is presently not available. For example, degradation is a concern for reefs near population centers, but water quality monitoring of contaminants and nutrients is generally lacking. Standardized water quality monitoring must be initiated for those reef systems that currently do not have adequate coverage or may not be monitoring the same parameters. This will help identify and quantify causes of degradation for the next biennial report.

The remainder of this Section presents generally accepted indicators of ecosystem condition that will be evaluated and reported on every two years. Most of the information is now **qualitative**[92] but more should be **quantitative**[93] in the near future. This information forms the scientific baseline on which future authors can note any change in ecosystem condition, and on the basis of their findings, prepare respective assessments of coral reef ecosystem condition. As it becomes more refined, this data may be used to track and forecast ecosystem change. It will also be useful in evaluating conservation management effectiveness. This was called for in the Coral Reef Conservation Act of 2000.

Prior to 2001, except for Florida, none of the jurisdictions had long-term, ecosystem-wide monitoring of representative habitats[94]. Monitoring of reef fish at randomly selected sites using NOAA's digital benthic habitat maps began in the USVI and Puerto Rico in 2001 (Christensen *et al.* in press). This kind of rigorous monitoring, based on comparable benthic habitats, is needed to prepare quantitative spatial trend assessments for the next biennial report.

**Reef Characterization** – U.S. shallow-water coral reefs are roughly computed to cover 7,607 mi$^2$ (19,702.4 km$^2$), with an additional 4,479-31,470 mi$^2$ (11,600-81,500 km$^2$) off the Pacific Freely Associated States. Pacific values, comprising the bulk of reef estimates in this table, are mostly estimates from Hunter (1995).

All major reef types can be found off the U.S. and Freely Associated States (Table 4). Also, the U.S. has several unique reef-associated habitats.

Human access to coral reefs ranges from those easily reached from nearby urban centers to remote reefs accessible only by ship (Fig. 97).

**Ecosystem Habitat Cover** – For this initial report, reef ecosystem cover is mostly based on qualitative judgments, since there are few places with adequate quantitative data. Only off Puerto Rico and the USVI have shallow-water coral reef ecosystem habitats been mapped and habitat cover relatively determined throughout the jurisdiction.

Estimates of percent reef cover in Table 5 for Puerto Rico and the USVI are based on NOAA results from recent mapping of reefs around these islands. For all other reef areas, percent reef cover figures are from monitoring data; sometimes these have have been calculated from only a few transects taken at a small number of sites.

One general conclusion from this table is where stony corals are degraded or have succumbed to environmental pressures, the ecosystem responds

[92] Descriptive, not based on robust data.

[93] Comparisons based on reliable measurements of standardized parameters.

with an increase in macroalgae. This makes it more difficult for coral larvae to find appropriate surfaces to settle out, thereby perpetuating degraded reef conditions.

**Biological Diversity** – The flora and fauna of reef ecosystems in the United States and the Freely Associated States are diverse, evolutionarily derived from Caribbean, Gulf of Mexico, Atlantic, Pacific, and Indo-Pacific faunal assemblages. The diversity of native, endemic, and alien species varies across systems, as does their degree of exposure to natural and human-induced pressures. The highest biological diversity occurs in the Indo-Pacific region (e.g., the Freely Associated States).

No census of all species inhabiting coral reefs within the United States or the Pacific Freely Associated States has ever been conducted. Neither is there a single comprehensive list of coral reef ecosystem species for any jurisdiction. Data were compiled from individual surveys conducted by different investigators at different reefs using different methodologies sometimes separated by decades. These are presented in Tables 6-9. They are a combination of rigorous collecting and species verification by experts, or, due to a lack of data, are reasonable estimates of how many species should be in the ecosystem. Where there is no notation on a table, managers lacked credible data and have identified these gaps as priority items.

Although the FKNMS seems to be well inventoried, their data are the result of integrating a series of investigations over a number of years for different parts of the region. Some records are over 20 years old. Even within the FKNMS, there were

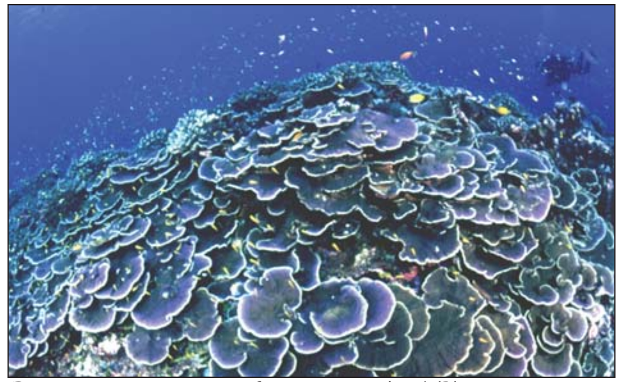


*Figure 97. A remote reef at Jarvis Island (Photo: James Maragos).*

dramatically different numbers for the same **taxa**[95], so the authors of this report included citations for each selected value. See the jurisdictional reports for specific information. Lacking a master list, it was impossible at this time to report known species for all reefs in Florida, so the authors chose to report what is known for the FKNMS. In some cases, FKNMS values were well above those reported for the entire state.

As with Florida, other reef systems had inconsistencies among researchers concerning the actual count of reef biota even in regions where the data were quantitative. A number of coral reef ecosystems, however, still need a basic inventory of species. For this reason, no notation appears for much of the biota from many of the Pacific Island groups, Puerto Rico, and the USVI. Additionally, there is likely considerable duplication among the various scientific surveys conducted through the years on different reef ecosystems. These need to be integrated into a single list.

*Table 5. Percent cover of benthic organisms on coral reefs in the United States and the Freely Associated States (Photo: James Maragos). *Only information for FKNMS has been included here, because data for other areas of Florida are generally not available.*

| | Florida Keys* | | Puerto Rico | | US Virgin Islands | | Flower Gardens | | Main Hawaiian Islands | | Northwestern Hawaiian Islands | | American Samoa | | Guam | | Northern Mariana Islands | | U.S. Remote Insular Reefs | | Marshall Islands | | Federated States of Micronesia | | Palau | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Reef cover (%/trend) | Good to fair | | Good to fair | | Good to fair | | Excellent | | Good to excellent | | Excellent | | Good to excellent | | Poor to excellent | | Good to excellent | | Good to excellent | | Good | | Good to excellent | | | |
| Stony corals | 6.6 | ↙ | 15.1 | | 25 | ↙ | 51.8 | Ø | 18 | ↙ | | | | ↗ | | ↙ | | | | | | | | | 60 | |
| Soft corals | 1.6 | Ø | | | | | 0 | | | | | | | ↗ | | | | | | | | | | | | |
| Macroalgae | 76 | ↗ | 1.9 | | 6.4 | ↗ | 2.7 | Ø | | ↗ | | | | ↙ | | | | | | | | | | | | |
| Seagrasses | 50-75 | Ø | 12.5 | | 6.9 | | 0 | Ø | | ↙ | 0 | | | | | | | | 0 | Ø | | | | | | |
| Mangroves | 1 | Ø | 1.4 | | <1 | | 0 | Ø | >1 | ↗ | | Ø | | ↙ | | | | | 0 | Ø | | | | | | |
| Sponges | 3.5 | Ø | | | | | 1.5 | Ø | <1 | | | | | | | | | | | | | | | | | |

*Key: ↗=Increase ↙=Decrease Ø =No change*

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[94] Not just coral reef, but seagrass, algal, sand, hardbottom, and mangrove habitats.

[95] For example, the number of species of mollusks differed among investigations as much as an order of magnitude. The term **taxa** (singular **taxon**) is the name given to biologically related groups of organisms (e.g., mollusks, crustaceans) in the scientific discipline of **taxonomy**.

| Species diversity (# species) | Florida | Puerto Rico | US Virgin Islands | Flower Gardens | Main Hawaiian Islands | Northwestern Hawaiian Islands | American Samoa | Guam | Northern Mariana Islands | U.S. Remote Insular Reefs | Marshall Islands | Federated States of Micronesia | Palau |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Algae | 367 | 500 | | 44 | >400 | ~200 | 80 | 306 | 150 | | | 222 | |
| Endemic | 0 | 0 | | 0 | >85 | | 0 | | | | | | |
| Seagrasses | 7 | 6 | 5 | 0 | 2 | 2 | | 4 | 3 | 0 | 3 | | |
| Endemic | 0 | 0 | | 0 | 1 | 1 | 0 | | | 0 | | | |
| Mangroves | 3 | 4 | | 0 | | | 3 | 10 | 1 | 0 | 5 | 14 | |
| Endemic | | | | 0 | 0 | 0 | | | | 0 | | | |
| Endangered/ threatened | 1 | | | | 0 | 0 | | | | | | | |
| Alien | 0 | | | | 19 | 1 | | | | | | | |

*Table 6. Marine plant species found in coral reef ecosystems in the United States and Freely Associated States (Photo: Matt Kendall).*

To rectify this situation, NOAA and its partners are proposing to create and maintain a list of all U.S. coastal marine species on a web site with public access. This inventory effort will begin in 2002 as a Pilot Prototype Project for the Hawaiian coral reef ecosystem. With so many coral reef ecosystems now being characterized, many new species will probably be identified in the next report.

**Marine Algae and Higher Plants** – Across regions, there is great variance in species composition and the total number of marine plant species (Table 6). While there are as many as a dozen seagrass species in a given region, there could be hundreds of macroalgal species. The number of macroalgal species ranges from a low of 44 species on FGBNMS reefs to a high of 500 off Puerto Rico. There are several reef systems (USVI, U.S. remote insular reefs, FSM, and Palau) where algal surveys are needed. Most likely the number of macroalgal species will greatly expand when in-depth surveys are completed, filling the gaps in this table.

Alien plant species are a problem in some areas. In the Caribbean, native mangroves are nursery habitats and provide shelter for juveniles of many reef invertebrate and fish species. In Hawai‘i, however, alien macroalgae and red mangrove (*Rhizophora mangle*) are a major problem, displacing native species, some of which may be rare endemics.

**Corals and other Invertebrates** – The condition of reef invertebrates is highly variable from region to region. Diseases in corals and other invertebrates are generally higher in the Caribbean. While recruitment is one of the primary measures of coral health, only three jurisdictions currently monitor this parameter. Standardization and implementation of monitoring for this health indicator is one of the near-term goals of NOAA's National Monitoring Network.

Stony corals comprise anywhere from 28 species in FGBNMS to 425 species off Palau (Table 7).

Not as diverse, soft coral species range from none in the FGBNMS to 120 off Palau. Sponge species are also highly variable among regional reefs, ranging from less than 27 in the FGBNMS to over 300 off Palau. Most likely the numbers are high in the insular reefs; they have not been well surveyed.

Among the many species of invertebrates that inhabit coral reefs, **mollusks**[96] are probably the most biologically diverse. Well over a thousand species have been identified from many reef systems (Table 7).

Next to the mollusks in diversity, **crustaceans**[97] range from a low of 62 species on the FGBNMS to over 884 species off the Main Hawaiian Islands. Small shrimp-like species of crustaceans[98] are the

[96] Clams, snails, octopi, and squids.
[97] Crabs, lobsters, and shrimps.
[98] Mysids, amphipods, copepods, and isopods.

prey of larger invertebrates, finfish, seabirds, and marine mammals.

Relatively diverse but difficult to identify, **annelids**[99] are not well inventoried on many reefs. The most complete inventory of these to date lists over 200 species recorded from the MHI.

The often large and colorful **echinoderms**[100] are important reef species, yet many reefs need surveys of what species exist and what their niches are within respective habitats. Note the many gaps on Table 7. Echinoderm diversity ranges from 15 species in the CNMI to over 278 species from coral reefs in the MHI.

*Figure 98. Crown-of-thorns starfish on American Samoa (Photo: Charles Birkeland).*

Echinoderms are considered **keystone** species because their impact on the rest of the coral reef ecosystem can be significant. Two in particular – the algae-eating long-spined sea urchin and the crown-of-thorns starfish. Both have had major impacts. In different ways, both have devastated reef-building corals across entire regions.

Scientists determined that the loss of long-spined urchins has changed the structure and perhaps function of Caribbean reef ecosystems. Decimated by disease in the early 1980s, these urchins have not yet recovered to any significant degree. In the 1970s, crown-of-thorns starfish were responsible for heavy mortality of corals off American Samoa (Fig. 98), the southern islands of the CNMI, Guam, and other Micronesian islands (Marsh and Tsuda 1973). But by 1981, many reefs had reasonably recovered. Then in the mid-1980s, smaller outbreaks of starfish were associated with coral mortality at some Indo-Pacific reefs, but again recovery was relatively rapid (Birkeland 1997b, Green 1997). In recent years, these starfish have not been a major problem; however, new aggregations were reported recently at Palmyra Atoll (J. Maragos pers. comm.).

Invertebrate alien species are also a problem, particularly in Hawai'i. Eldredge and Englund (2001) consider more than 250 marine invertebrates to have been introduced to Hawaiian waters. Less is known about alien species introduced to other reef systems.

**Finfish and Fisheries** – Generally the data for fish diversity is more robust than for other taxa. Much of the data to determine fisheries condition, however, is not consistent. Although the parameters monitored for commercial fisheries vary somewhat among jurisdictions, the larger problem is that, with the exception of Florida, there is practically

*Table 7. Coral and invertebrate species diversity and condition in reef ecosystems in the United States and Freely Associated States (Photo: Mohammed Al Momany). *Only information for FKNMS has been included, because not all types of data are available from other areas of Florida.*

|  | Florida Keys* | | Puerto Rico | | US Virgin Islands | | Flower Gardens | | Main Hawaiian Islands | | Northwestern Hawaiian Islands | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species diversity (# species/#endemics)** | | | | | | | | | | | | |
| Stony corals | 64 | 0 | 43 | 0 | ~40 | 0 | 28 | 0 | 50 | 14+ | 52 | 10+ |
| Soft corals | 55 | 0 | 42 | 0 | | | 0 | 0 | | | | |
| Sponges | 117 | 0 | | 0 | | | 27 | 0 | >100 | 30 | | 7+ |
| Polychaetes | 89 | 0 | | 0 | | | 20 | 0 | >200 | 80 | | |
| Mollusks | 1200 | 0 | 1100 | | 0 | | | 667 | 0 | 1071 | 200 | 350 |
| Crustaceans | 371 | 0 | | 0 | | | 62 | 0 | 884 | | | |
| Echinoderms | 82 | 0 | | 0 | | | 36 | 0 | 278 | 150 | | |
| **Endangered/alien (# of species)** | 1 | 0 | | | | | | | 0 | 20+ | 0 | |
| **Coral recruitment (#/m2)** | 2-10 | | | | | | | | 1.7-2.3 | | | |
| **Diseases (impact/trend)** | High | ⇗ | High | | High | | Low | Ø | | Ø | None | Ø |
| **Bleaching mortality** | High | | Medium to high | | Low | | Low | | Low | | Low | |

| | American Samoa | | Guam | | Northern Mariana Islands | | U.S. Remote Insular Reefs | | Marshall Islands | | Federated States of Micronesia | | Palau | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species diversity (# species/#endemics)** | | | | | | | | | | | | | | |
| Stony corals | ~200 | 0 | 403 | | 256 | | 0 | 150 | | 250 | 1 | | | 425 |
| Soft corals | | 0 | 77 | | 41 | | <10 | | | | | | | 120 |
| Sponges | | 0 | 128 | | | 28 | | | | 40 | 0 | | ~300 | |
| Polychaetes | | 0 | 104 | | | | | | | | | | | |
| Mollusks | | | 0 | 1673 | | 2 | 520 | 2 | | | 1655 | | 1 | |
| Crustaceans | | | 0 | 825 | | 101 | | | | 728 | 3 | | | |
| Echinoderms | | 0 | 194 | | | 15 | | | | 126 | 1 | | | |
| **Endangered/alien (# of species)** | | | | | | | | | 11 | | | | | |
| **Coral recruitment (#/m2)** | | | .026-.058 | | | | | | | | | | | |
| **Diseases (impact/trend)** | | Ø | | | Low | Ø | | | | | | | | |
| **Bleaching mortality** | Medium | | | | Medium | | Medium | | | | | | High | |

*Key: ⇗=Increase ⇙=Decrease Ø=No change*

[99] Large polychaetes (segmented worms like bristle worms and the Samoan palolo worm) are better inventoried, but the oligochaetes and leeches are virtually unknown.

[100] Seastars, ophiuroids, and brittle stars.

|  | Florida Keys* | Puerto Rico | US Virgin Islands | Flower Gardens | Main Hawaiian Islands | Northwestern Hawaiian Islands | American Samoa | Guam | Northern Mariana Islands | U.S. Remote Insular Reefs | Marshall Islands | Federated States of Micronesia | Palau |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species diversity (# species) | | | | | | | | | | | | | |
| Marine fish | 517 | 571 | 532 | 266 | 1172 | 266 | | 1105 | | | 1052 | 1125 | 1361 |
| Reef and shore fish | 389 | 242 | 246 | ~236 | 557 | 258 | 890 | 1019 | 1019 | | 860 | 873 | 1278 |
| Endemics | 0 | 0 | 0 | 0 | 120 | | 0 | 4 | 3 | | 7 | 5 | 2 |
| Endangered/threatened | 4 | 11 | 11 | | 8 | | 7 | 8 | 7 | | 6 | 7 | 9 |
| Alien | 0 | 30 | 6 | | 13 | 3 | 4 | 17 | 2 | | 1 | 2 | 4 |
| Diseases (presence/trend) | √ Ø | | | | √ | None Ø | | | | | | | |
| Fisheries condition | Overfished | Overfished | Overfished | Healthy | Overfished | Healthy | Overfished | Overfished | | Healthy | | Overfished** | |

Key: ⇩=Increase ⇧=Decrease Ø=No change

*Table 8. Fish species diversity and condition in coral reef ecosystems in the United States and Freely Associated States (Photo credit: FKNMS). *Only information for FKNMS has been included, because not all types of data are available from other areas of Florida; **Refers to Chuuk only.*

no monitoring of recreational and artisanal fisheries. That is the reason why only ex-vessel commercial fisheries data are summarized.

The number of marine fish species identified from coral reef ecosystems is diverse, ranging from around 266 species in the FGBNMS and the Northwestern Hawaiian Islands to over 1,300 from coral reefs off Palau (Table 8). Likewise, reef-associated and shore species vary among regions from around 200 to over 1,200. The highest number of alien fish species have been identified from coral reef ecosystems in Puerto Rico (30), Guam (17), and Hawai'i (13). The largest number of endemic species is found on Hawaiian near-shore coral reef ecosystems (120).

Although fish diseases and fish kills have been reported off Florida and the Main Hawaiian Islands, the status of reef fish diseases is mostly unknown. The National Monitoring Network will encourage measuring and monitoring this parameter.

*Figure 99. Humpback whales (Photo: N MFS).*

Reef fish populations are considered healthy in the FGBNMS, Navassa, and the NWHI. Elsewhere, most areas have been overfished. For some regions, fish condition is not known (note the gaps in Table 8).

Marine Reptiles and Mammals – Six species of sea turtles have been identified on U.S. coral reefs (Table 9). These marine reptiles only come ashore to lay eggs. Three species[101] are found on occasion by Caribbean divers, but two additional species[102] are rarely sighted (Humann 1994). Sea turtles are also found in the Pacific along with olive ridleys.

According to G. Paulay (pers. comm.), two species of sea snakes are known from Palau – the egg-laying banded sea snake (*Laticauda colubrina*), and the viviparous yellowbellied sea snake (*Pelamis platurus*), a pelagic species ranging from East Africa to the Pacific coast of the Americas (Allen and Steene 1996). There are anecdotal accounts of the latter from the CNMI and the Federated States of Micronesia.

As many as 27 species of marine mammals, including porpoises, sea lions, seals, and whales, have been identified. One of the more spectacular species, the humpback whale (*Megaptera novaeangliae*) spends the winter near Mexico and Hawai'i to breed and calve, and then adults and their youngsters journey back to Alaska each summer to feed (Fig. 99). Spinner dolphins (*Stenella longirostris*) are common and form large schools that are often seen daily in the same areas (Fielding and Robinson 1987).

**Water Quality** – U.S. coastal beaches and drinking water are monitored regularly for parameters

[101] Loggerhead, hawksbill, and green sea turtles.
[102] Leatherbacks and Atlantic Ridleys.

| | Florida | | Puerto Rico | | US Virgin Islands | | Flower Gardens | | Main Hawaiian Islands | | Northwestern Hawaiian Islands | | American Samoa | | Guam | | Northern Mariana Islands | | U.S. Remote Insular Reefs | | Marshall Islands | | Federated States of Micronesia | | Palau | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species diversity (# species/# endemics) | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Turtles | 5 | 0 | 3 | 0 | 3 | 0 | 2 | 0 | 6 | 0 | 2 | 0 | 2 | 0 | 3 | 0 | 2 | 0 | 2 | 0 | 5 | 0 | | 0 | 4 | 0 |
| Marine mammals | 23 | 0 | 21 | 0 | | | 4 | 0 | 24 | 1 | | 1 | 2 | 0 | 13 | | 10 | | 1 | | 27 | | | | 2 | |
| Endangered/threatened (# species) | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Turtles | 5 | 0 | 3 | 0 | 3 | 0 | 2 | 0 | 5 | 0 | 2 | 0 | 2 | 0 | 3 | 0 | 2 | 0 | 2 | 0 | 5 | 0 | | 0 | 1 | 0 |
| Marine mammals | 7 | 0 | 21 | 0 | | 0 | | 0 | 19 | 0 | | 0 | 1 | 0 | | 0 | | 0 | | 0 | | 0 | | 0 | 1 | 0 |
| Turtle fibropapillomas (impact/trend) | High | ⬀ | Low | ⬀ | | | | | High | Ø | None | Ø | None | Ø | | | | | | | | | | | | |

Key: ⬀=Increase ⬃=Decrease Ø=No change

*Table 9. Marine mammal and sea turtle species diversity and condition in the United States and Freely Associated States (Photo: Ursula Keuper-Bennet and Peter Bennett).*

affecting human health using EPA prescribed methodologies for 305(b) reports[103].

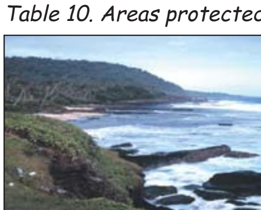
Many jurisdictions monitor coastal near-shore waters for dissolved oxygen, turbidity, fecal coliform, enterococcus, oil and grease, selected toxic metals, ammonia, nitrate/nitrite, and pH (e.g., American Samoa, Guam, CNMI). As an example of the longevity and breadth of EPA prescribed monitoring, the Puerto Rico Environmental Quality Board has been monitoring physical, chemical, and bacteriological parameters at 88 stations along its coastal zone since 1982. Because this monitoring follows prescribed methodologies, the data should be comparable and useful in determining temporal trends in water quality. This testing, however, is for parameters affecting human health, some of which may be more useful than others for determining coral reef health.

A few jurisdictions go beyond this set of parameters. They also monitor for toxic metals and organic chemicals[104]. With NOAA and the EPA, the FKNMS has been monitoring an array of water quality contaminants at fixed stations. To track changes in water quality affecting coral reefs nationally, the Coral Reef Program is encouraging the addition of certain key water quality indicators to its National Coral Reef Monitoring Network.

Because the water quality data for some of the jurisdictions covered in this report were qualitative or not available, spatial and temporal trends for water quality cannot be assessed nationally. Managers from the FKNMS, Puerto Rico, and American Samoa, however, indicated that within their coral reef ecosystems, water quality had been deteriorating over the past decade. Not surprisingly, managers of reefs distant from human populations (the FGBNMS, the NWHI, and the U.S. remote insular reefs) all indicated that their reef systems had excellent water quality. The remainder had varying degrees of water quality problems within their jurisdiction.

The quantity and quality of reef organisms depends on water quality. Areas next to densely populated shorelines generally have poorer water quality than areas far from human habitation. The impact on the diversity and abundance of organisms in those degraded areas is generally lower, correlating directly with water quality and habitat condition.

*Table 10. Areas protected by MPAs and no-take reserves (Photo: Kip Evans).*



| | Florida | Puerto Rico | US Virgin Islands | Flower Gardens | Main Hawaiian Islands | Northwestern Hawaiian Islands | American Samoa | Guam | Northern Mariana Islands | U.S. Remote Insular Reefs | Marshall Islands* | Federated States of Micronesia | Palau |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Federal MPAs | 11 | 1 | 3 | 1 | 4 | 3 | 3 | 2 | 0 | 7 | | 0 | 2 |
| State/Territorial MPAs | 2 | 32 | 5 | 0 | 30 | 0 | 1 | 8 | 7 | 0 | | 2 | 11 |
| No-take areas ($km^2$) | 724.9 | 11.0 | 51.8 | 0 | 5.2 | 2469 | 10.4 | 28.0 | 9.6 | 132 | | | 65.3 |
| Percent no-take area | ~5% | 1.5% | 17.4% | 0% | 0.3% | 21.4% | 3.5% | ~28% | 1.7% | 30.3% | | | 3.9% |

[103] Coastal zone water quality monitoring required for human health.

[104] Pesticides, herbicides, PAHs, PCBs, dioxins.

**Marine Protected Areas (MPAs) and No-Take Reserves –** As of 2002, there were 120 (35 Federal and 85 State/Territorial) MPAs in the United States and 15 MPAs in the Pacific Freely Associated States (Table 10). These provide variable levels of protection to the reefs, ranging from open harvest access to full enforcement of no-take provisions. Coral reef MPAs include National Marine Sanctuaries; National Parks, Seashores, Monuments, and Wildlife Refuges; and National Estuarine Research Reserves and Estuary Program areas. There are also State, Territory, and Commonwealth Parks, Conservation Areas, and Reserves.

Fishery Management Plans have also designated MPAs for habitat protection, rebuilding fish stocks, and for critical habitats of threatened or endangered species.

U.S. marine areas protected by no-take provisions cover 1,329 mi$^2$ (3,442 km$^2$), while another 25.2 mi$^2$ (65.3 km$^2$) of no-take reserves protect Palauan reefs. Realistically, the percentage protected by no-take provisions within most jurisdictions most likely will change when the coral reefs are entirely mapped.

For this report, it was deemed impossible to calculate the total reef area protected by no-take provisions across all jurisdictions because over 85% of reef-associated benthic habitats have yet to be mapped[105]. The authors of this report concluded that state-of-the-art shallow-water mapping needs to be completed before this could be done with confidence.

A synthesis of more than 100 studies of reserves worldwide shows protection from fishing leads to increased biomass, abundance, average size, and species diversity (Halpern in press). Because marine reserves contain more and larger fish, protected populations can produce more offspring. Roberts *et al.* (2001) demonstrated that reserves serve as sheltered nurseries. Large fish move to waters adjacent to the reserve through density-dependent spillover of juveniles and adults[106].

This is seen around the Merritt Island National Wildlife Refuge. It is one of the oldest, fully protected marine reserves, closed to fishing since 1962 for security of the Kennedy Space Center. Roberts *et al.* (2001) report that sport fishers around this 40 km$^2$ Reserve have landed a disproportionate number of world- and state-record fish. It accounts for 62% of 39 records for black drum,


*Figure 100. NOAA enforcement of regulations in FKNMS (Photo: Paige Gill).*

54% of 67 records for red drum, and 50% of 32 records for spotted sea trout. Preliminary results from monitoring some of the more recently designated U.S. no-take reserves have similar information on their effectiveness.

To directly assess the effectiveness of no-take marine reserves in the FKNMS, NOAA conducted diver surveys in the Florida Keys and the Tortugas Ecological Reserve. The results after three years of monitoring, the FKNMS' zone network showed populations protected by no-take provisions improved significantly. Despite population declines elsewhere, numbers of some fish species in the fully protected zones of the Sanctuary are increasing. Analyses of three years of reef fish abundance data show that **mean densities**[107] for several economically important exploited fish species[108] are higher in the Sanctuary Preservation Areas (SPAs) than in fished reference sites (Bohnsack *et al.* 2001). Complementing these data, gray snapper (*L. griseus*), schoolmaster (*L. apodus*), and yellowtail snapper are increasing after fully-protected zones were established in 1997 at 16 sites monitored by Reef Environmental Education Foundation volunteers (Pattengill-Semmens 2001).

Legal-size spiny lobsters continue to be larger and more abundant in SPAs than in reference sites of

[105] One of many such examples, Statewide mapping is not yet available to the level of that already established in the FKNMS, so the percentage of coral habitat protected by no-take provisions is still only a reasonable estimate (i.e., 10%) for the FKNMS and not for all Florida.

[106] As the fish populations within the protected area grow in both numbers and size of individuals, competition between the largest drives some of them into adjacent waters.

[107] The average number of individuals per sample area.

comparable habitat (Cox *et al.* 2001). At all times of the year **catch rates**[109] are higher within the Western Sambo Ecological Reserve than the two adjacent fished areas (Gregory 2001). This is not so, however, for the overfished queen conch. They have remained low despite a ban in the mid-1980s on both commercial and recreational harvesting.

**Coral Reef Governance and Management** – Federal, State, Territorial, and Commonwealth agencies are responsible for the conservation of living marine resources, including fisheries, marine mammals, and endangered and threatened species within the **Exclusive Economic Zone**[110] (EEZ, Fig. 100). Legislation provides the authority for managing coral reef ecosystems (Appendix IV). These include Fishery Management Plans, management of MPAs, and protection of reef species and resources of concern[111].

Fishery Management Plans written by Fisheries Management Councils govern commercial fishing throughout the EEZ, regulating harvests by annual catch quotas, closed seasons, gear restrictions, and minimum catch sizes. Most governments collect **landing data** (data collected at the dock or from creel surveys) on the kinds of fish, invertebrates, and plants taken that can be used to track trends and evaluate the effectiveness of regulations.

*Figure 101. In the U.S. Western Pacific region, jacks are managed by the Bottomfish FMP (Photo: James Maragos).*

In most regions, the management of coral reef resources[112] is jointly undertaken by local and Federal agencies. Within three miles from shore, local agencies generally manage fisheries and other uses of coastal resources. A variety of legislation gives NOAA the authority to manage living marine resources in U.S. Federal waters[113]. Federal fisheries regulations are implemented by the Secretary of Commerce and enforced by NOAA's National Marine Fisheries Service (NMFS).

**Fisheries Management Plans** – Four of eight Regional Fishery Management Councils have developed federal Fishery Management Plans (FMPs) for reef fisheries resources and proposed implementing regulations. They are as follows.

Gulf of Mexico Fishery Management Council – NOAA manages a number of fisheries associated with coral reefs based on FMPs, including Coral and Coral Reefs, Red Drum, Reef Fish Resources, Spiny Lobster, and Stone Crab. This Management Council also identified the Madison-Swanson and Steamboat Lumps Marine Protected Areas on the West Florida Shelf as potential reserves. NOAA designated them as such and since has been assessing their resources and fisheries contribution.

South Atlantic Fishery Management Council – Coral reef associated fisheries managed under FMPs in the South Atlantic include Atlantic Coast Red Drum; Coral, Coral Reefs, and Live/Hard Bottom Habitats of the South Atlantic Region; Golden Crab; Snapper-Grouper Fisheries; and Spiny Lobster. This Council proposed the no-take zones for the new Tortugas Ecological Reserve.

Caribbean Fishery Management Council – Reef-associated fisheries of Puerto Rico and the USVI managed under FMPs developed by the Caribbean Fishery Management Council in-clude Corals and Reef-Associated Plants and In-vertebrates; Queen Conch; Reef Fish; and Spiny Lobster.

Western Pacific Regional Fisheries Management Council – Three FMPs developed by this Council include coral reef resources. The Bottomfish FMP regulates fishing primarily for snappers, groupers, and jacks (Fig. 101) in the EEZ around the Territory of American Samoa, Territory of Guam, State of Hawai'i (including the NWHI), the Commonwealth of the Northern Mariana Islands, and U.S.

[108] Gray snapper (*Lutjanus griseus*), yellowtail snapper, and grouper (several economically important species were combined).

[109] Generally this term is dependent on the method of capture; as used here, it is the number of lobsters per trap.

[110] The term Exclusive Economic Zone (defined by the Magnuson-Stevens Fishery Conservation and Management Act at 16 U.S.C. 1802, Section 3) is the zone established by Proclamation 5030, dated March 10, 1983. To apply the Act, the inner boundary of that zone is a line coterminous with the seaward boundary of each of the coastal states. The outer limit of the EEZ is 200 miles from the inner boundary.

[111] Endangered species and the taking of live rock.

[112] Mapping, research, and monitoring activities, as well as management and enforcement of any regulatory provisions.

[113] Federal waters are generally defined as being from the seaward boundaries of the respective State and Territory jurisdiction to the outer boundary of the EEZ (defined above).

Pacific insular remote reefs. The Crustaceans Fishery FMP targeted spiny and slipper lobsters in the NWHI by limiting the number of entry fishery permits (15 maximum) of which fewer than half are usually active in any one year. The crustacean fishery has been closed since 2000 pending the resolution of uncertainties in the current stock assessment model.

The Precious Coral Fishery FMP operates in one area off the MHI. Although this has also been permitted, it has not operated in the NWHI for over 20 years.

A Draft FMP for Coral Reef Ecosystems of the Western Pacific Region has been completed and is now under NOAA and DoC review. This proposed FMP has provisions for marine protected areas (including no-take zones), special permits for new fisheries, and limitations on permitted fishing gear. NOAA has not yet approved the Draft FMP.

**Regulations and Enforcement** – Regulations have been developed for most commercially important fisheries. Those applicable to coral reef ecosystems vary among jurisdictions and cover quotas on catch, closed seasons, closed areas, gear restrictions, and minimum catch sizes. Other regulations protect coral reef resources by regulating oil exploration and mining, setting up no-anchor zones, regulating coastal construction, and imposing water quality and pollution controls.

All of the nearly 100 jurisdictional managers and experts developing this report agreed enforcement was not adequate to protect coral reef ecosystem resources. This is an especially difficult task for the larger and more remote reef systems with jurisdictions that lack the ships and staffing to adequately patrol their MPAs.

To support the need to better protect reefs, the USCRTF has called for better enforcement of laws, established new guidance to protect coral reefs, and provided funding and technical assistance to states and territories to build **management capacity**[114].

[114] Whatever management measures may be needed to conserve coral reef ecosystems. Many of the island agencies asked for federal support to build their local capacity to conduct a long-term monitoring and assessment program for their coral reef ecosystems. NOAA, through grants to island jurisdictions, has funded a variety of management activities since 2000 that include hiring full-time, permanent technical staff, purchasing equipment, and conducting various workshops.